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PHYSICS.—*Atomicity and patterns.*[1]

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Joseph Henry was a man of very versatile mind, as the wide range of his work shows. He lived, moreover, in an age in which science was far less compartmentalized than it is now, and I hope that you will not think it out of place if I speak to you to-day on a subject which covers a wide range, a subject on which indeed I have no new discovery to tell you, except to try to emphasize a point of view which is perhaps somewhat neglected. In the realm of nature there is one characteristic which appears again and again, but which does not seem to have been given in general a name. I mean the existence of large numbers of individuals of a particular kind, nearly or quite indistingiushable from one another. This characteristic ranges through the whole scale of the material world, from electrons to galaxies; each exists in countless numbers. But what makes the effect, in my opinion, more remarkable, is that it is not limited to dead matter. On the contrary, the most striking manifestations of it are in biology. The individuals of a species, whether from bacteria or human beings, are an obvious (but not the only) example. The same principle pervades the whole of biology. It is the principle of cellular structure, and it also applies to many of the organs of individual creatures. The hairs on a dog's back, the leaves on a beech tree, are alike, examples of the love of production in large numbers which pervades nature. Henry Ford may have supposed that he was initiating something new when he gave us mass production in its most characteristic form, but he was merely a humble imitator of nature, and though his cars were possibly more similar than the proverbial peas, they could not rival for a moment the identity of atoms or molecules. Nature is the grand mass producer; for individuality you must turn to the works of men: to art.

It will be a convenience, I think, to introduce the word *atomicity* in a new sense, to mean a group of individuals which closely resemble one another. Thus the scales of all the herrings in the sea, or the collection of the galaxies, may alike be described as atomicities.

It was in physics that the name "atom" was first applied, or rather in the natural philosophy of the Greeks and Romans. Starting from an almost legendary Leucippus, the idea was developed by Democrates and Epicurus, but far the best statement of it is by the Roman Lucretius, whose work survived the Middle Ages in a single copy more, I suspect, because of its poetic beauty than for its very great scientific merit. Lucretius was a poet; I believe he took most of the ideas from his Greek predecessors, but they are very remarkable ideas. Not merely is the general statement of atoms as constituents of matter introduced and amplified, but one can find traces of the most up-to-date discoveries of physics—no doubt this is partly a case of the reader finding what he has himself brought, but it may possibly be a little more. Lucretius anticipates Prout's hypothesis that atomic weights are integral multiples of a unit. He does so from an argument which does not hold water, but at least he makes the statement. He has, it is true, no idea of molecules, but he anticipates in an astonishing fashion one of the great advances of the quantum theory—the idea of indeterminacy. His atoms fall through empty space; for him

[1] The 25th Joseph Henry Lecture of the Philosophical Society of Washington, delivered before the Society on April 20, 1956.

there is an absolute vertical; he has no idea of universal gravitation; but although his philosophy is, on the whole, deterministic, he introduces the "clinamen," an arbitrary motion designed to upset the regularity of the downward motion, and be the cause of the collisions which he rightly regards as the fundamental condition for happenings. Except for these, he says, nature would create nothing. He realizes that the arbitrary nature of these assumed motions prevents a complete causal sequence.

"Lest cause should follow cause in endless sequence," he says, and ends the passage[2]: "Hence is this power torn from fate, I say, by which we walk as will points out the way." It is all strangely reminiscent of Heisenberg and the uncertainty principle!

In modern physics, of course, the ideas have been carried further, and what are still called "atoms" are no longer impossible to divide, but are made of electrons and nuclei. The electrons are identical, not merely in practice but in principle, and have no individuality. The same is true of the particles that make up the nucleus, protons and neutrons. It is difficult to know quite what position to assign to the mesons—the π mesons appear to be the particles responsible for the forces between nucleons (neutrons or protons), but they also by spontaneous decay pass to μ mesons, and these in turn to electrons. It is perhaps possible to regard them as in a kind of sense excited electrons, and some of the very heavy mesons recently discovered are apparently excited protons or neutrons. The meaning of these mesons is still very obscure, but at least they exist as a series with discrete masses and do not, I think, differ fundamentally in respect of atomic status from electrons or protons. It is somewhat different with quanta. Here indeed you have an atomicity, but with a continuous variation in a single property, what one may describe as a partial atomicity. Although quanta of the same frequency are identical, those of a different frequency are not. Yet this difference is, in a sense, artificial, since it is modified by the Doppler effect, while the Doppler effect does not alter the number of quanta in a given region.

Chemistry, which is in a sense the physics of the parts of atoms outside the nucleus, is in principle understood. Chemical combinations can be explained in terms of wave mechanics, and of the properties of equations whose nature is fundamentally determined by the number of electrons that take part. A single atom, apart from the nucleus, is a pattern of electrons round the nucleus. This business of patterns is, I think, very fundamental. The charge and mass of the electrons, and those of the nucleus do indeed come into the calculations, but the most important thing is the *number* of electrons. The atom is essentially a pattern of integers. It seems likely that the nucleus may be very much the same. It is true that in these two cases we have to consider different substances, electrons in the case of the outer part of the atom, protons and neutrons in the case of the nucleus. But the stress on integers is the same in both. It reminds one of the famous saying: "God made the whole numbers and men made the rest." The same thing occurs when one passes to chemistry. A chemical compound is a special pattern of electrons, a pattern which can in fact be plotted out by the methods of X-ray diffraction. Again patterns of integers, electrons, and individual nuclei form the molecule. Bind the molecules into a crystal, and you get a pattern on a larger scale but with the same integral properties. It is pure speculation, I admit, but I cannot help feeling that the constituent substances that we still have to use—electrons, protons, neutrons, and perhaps mesons, will in the long run themselves turn out to be patterns—patterns of what? It will not be necessary to answer, for where all the substances are the same you do not need a name. They would, so to speak, be patterns of the first order, nuclei and the electrons around them will be patterns of the second order, molecules of the third, crystals of the fourth, and so on, and the world of inanimate nature will become reduced to a series of patterns more or less perfect (since atoms may be ionized and crystals have defects, while gases and liquids lack the highest kind of order), but all patterns and all concerned with integers. It is strange to recall—I do not venture to say that it is significant—that this idea goes back to the time of Pythagoras. He stressed the importance of integers. His discovery of

[2] LUCRETIUS, *De rerum naturae*. II, line 257.

numerical relations between the lengths of a string that produced musical intervals is possibly the oldest recorded experiment in pure physics, and I cannot help a feeling of satisfaction that it should be so closely in tune with the modern ideas of quantum numbers and Eigenwerte. The Pythagoreans not merely regarded numbers as in some sense divine, but paid particular attention to the types of patterns which can be made by integers, e.g., triangular numbers.

Let us turn from the very small to the very large.

Though stars resemble one another considerably, and especially in mass, they are by no means identical, and there are at least two kinds of galaxies, with again minor variations; but there is a kind of order-of-magnitude agreement. A galaxy contains an order of 10^{11} solar masses, and different galaxies probably do not vary by more than one or two powers of 10. It is, I think, of interest to consider how these and other imperfect atomicities, as one may call them, in fact arise, to see if one can trace any common factor. Unfortunately the creation of stars and galaxies is still not fully explained. It is generally supposed to be due to an instability occurring in a continuous amount of gravitating mass if this is large enough, as was suggested by Jeans. But I am told that Jeans's original theory is unsatisfactory in certain points and has not been fully replaced. But at least one can see that a distribution into discrete objects will be more stable in certain circumstances than a uniform distribution, and it is reasonable to suppose that this has something to do with the origin of these objects. There is another class of imperfect and partial atomicity of which much more is known. I refer to eddies. If a liquid is streaming in a pipe with every particle moving along the axis at more than a certain speed, depending upon the size of pipe and rate of flow, turbulence sets in, as Reynolds showed many years ago. This turbulence consists essentially of sets of eddies. The eddies resemble quanta rather than electrons in that there is a continuous distribution in size. The smallest eddies are near the wall, and they increase in size as they go outwards. This turbulent action is now pretty well understood, and has been closely studied in connection with the boundary layer that forms on the wings of aeroplanes and on the hulls of ships. In this case the simple undifferentiated motion is unstable and breaks down into a more complicated atomicity.

If we turn to biology we find at once the cell as an atomic unit. There are many kinds of cells and their size may vary greatly up to the giant nerve cells of the squid which are about ½ mm diameter and 20 cm long. Ordinary cells are of order 20 μ. But the cells of one kind are of roughly comparable size. Physiology is not far enough advanced to say for certain what determines the size of a cell; it must be some question of balance between surface tension, electrical forces and diffusion. However the size is arrived at, it is possible to have not merely unicellular organisms all roughly alike, but to have a part of an organism made up of a vast number of closely similar cells. Cells have the power of reproduction, and after they have divided grow to their original size, or roughly so. In some way the particular size characteristic of a particular cell represents a stable value which is rapidly reached, but never greatly exceeded. In some way too the undifferentiated material out of which the organism grows is organized most suitably into units of a certain size. The conditions of stability in this case as in those of turbulence are, of course, quite different from those of static stability. There is no question of searching for the position of minimum energy. In both cases energy is available from outside, and as in the case of some electrical systems the tendency may be toward a state of maximum energy subject to certain constraints.

If one takes an extended view of atomicity it affects one's view of the so-called *cosmological principle*. This principle in its most complete form asserts that the universe when suitably smoothed out looks the same from all places and at all times. In a less complete form variation with time is allowed but not with space. This principle has been very widely used, but there are substantial objections to it as ordinarily stated. In the first place it apparently not merely throws out the baby with the bath water, but throws out the baby (or babies) and retains the water, and the babies are big, nothing less than galaxies! The striking thing about the night sky is precisely its nonuniformity,

the light comes from a discrete set of points which are of varying brightness, and are not distributed at random but grouped round the Milky Way, which itself is a unique feature. Clearly an observer on another star would see a substantially different pattern. Limiting observation to a single galaxy the principle is certainly quite untrue; the smoothing must proceed much further. It is supposed to hold as between galaxies, but even here the distribution is irregular as many galaxies form part of clusters, others do not. It is only on the very largest scale that the principle is not demonstrably false. On that very large scale it states that the distribution of matter and of the velocities this possesses are independent of the observer. But even here there is a restriction. At any place there is a privileged or "fundamental" observer, roughly speaking an observer at rest with regard to the average of the galaxies. We are, in fact, in such a position, for observations in different directions in space—as far as they are possible in view of the absorption due to clouds in our own galaxy—show galaxies roughly uniformly distributed and with apparent velocities which do not on balance vary with direction. Clearly an observer moving past the earth with a velocity say a quarter that of light would not see this isotropy because of the well-known relativistic effects on angles and velocities. Indeed such effects would exist even on a nonrelativistic view of aberration and Doppler effect.

The need to choose these privileged observers detracts rather from the principle, for some of the regularity observed is manufactured by the choice. However it appears that observers near the center of galaxies could be representatives of a set which would not be so arbitrary—some theorists specify them. Taking this set of observers it is postulated that each would see a distribution of galaxies with density and velocity each a function of distance only, and these two functions would be the same for all fundamental observers. There is here a point which seems to me to present some difficulty. The principle is concerned with a smoothed out distribution for it is usually assumed that the fundamental observers form a continuous set, yet all that can be observed at the distances at which alone the principle applies is the *discrete* set of galaxies. To apply the theory one has to consider as important just that aspect which the theory neglects.

I venture to suggest that what is useful in the principle is best expressed in terms of atomicity. What it really says is that there are a very large number of approximately similar galaxies and that their distribution in space is that of the molecules of a uniformly expanding gas, with the addition that if there is an edge we are not near it. This is all that the observations justify. The recent work at Cambridge (England) on the so-called radio stars allows observations deeper into space even than the 200-inch telescope. So far this work does not support the idea that galaxies are uniformly distributed in space. Assuming, as one must from the principle of cosmogony, that the proportion of radio stars to galaxies is constant, more radio stars imply an increased density of galaxies, and this is what Ryle[3] and his workers find at great distance.

It is well known[4] that there are some connections between cosmic and electronic data which appear in the form of nondimensional ratios leading to the same very large number about 4×10^{39}. Thus:

(1) $\dfrac{e^2}{\gamma m_p m_e}$ = ratio of electric to gravitational force of electron and proton = 2.28×10^{39}

(2) $\dfrac{cT}{\left(\dfrac{2e^2}{m_e c^2}\right)}$ = ratio of characteristic size of expanding universe to diameter of electron = 6.6×10^{39} or ratio of age of universe to time for light to cross electron.

(3) $\dfrac{\rho_0 c^3 T^3}{m_p}$ = number of protons in a volume characteristic of the universe = $[5.6 \times 10^{39}]^2$

(4) $\gamma \rho_0 T^2 \div 1$ which after reduction implies that the gravitational P.E. of a particle in the field of the universe is about equal to its rest mass.

Here ρ_0 is the mean density of matter in space; ρ_0 is taken as 10^{-27}: which may easily be wrong by two powers of 10. T is the reciprocal of Hubble's constant, with a

[3] Proc. Roy. Soc., A, **230**: 448. 1955.

[4] Cf. BONDI, *Cosmology*. Cambridge University Press.

probable value of about 4×10^9 years. The other constants are accurately known (c velocity of light, e charge of electron, m_e mass of electron, m_p mass of proton, γ universal constant of gravitation). In any case one would not expect such relations, if derived from some yet-to-be discovered fundamental theory, would be exact, factors of $\frac{1}{2}$, 2, 4π would be expected to occur.

But the agreement seems better than a coincidence and is one of the reasons for regarding atomicity as very fundamental in the universe, since atomic constants are related to cosmic ones. Dirac has suggested that these large numbers are not really constant but increasing steadily with time, and (2) can be regarded as the age of the Universe in natural units, but if so e, γ, m_e, or m_p must change with time. Eddington on the other hand regarded them as fixed by geometrical considerations and found for the number of elementary particles in the universe $N = \frac{3}{2} \times 136 \times 2^{256} \div 2.4 \times 10^{79}$.

Some modern theories of cosmogony, those of Bondi and Gold, and of Hoyle, require matter to be continuously created in the form of neutrons or hydrogen atoms, thus again implying a connection between the atomicity of the very small and cosmogony.

I understand from my biological friends that there is a tendency to reinstate the species as an important biological conception, but in any case there is no doubt that animals and plants of one general kind constitute an atomicity in our sense of the term. Even if there is a continuous gradation, as appears occasionally to happen in species that are widely distributed over the earth, so that individuals at the two ends of the range are markedly different, it yet remains true that there are a vast number of individuals which for practical purposes are indistinguishable and that is all that we need. How far can this be explained? To some extent the existence of species or, indeed, larger groups, is a consequence of the stability of the germ mechanism. Mutations indeed occur and abnormal individuals are born, although rarely. Among the normal individuals there is a gradation in all qualities, and rearrangement of genes can bring about changes within this range, of which some will be favored by natural selection and others discouraged. But the general effect is one of stability. Most of the creatures born to a particular pair are closely alike, and this process continued for generations produces a fairly homogeneous population. If large mutations were the rule and not the exception this would not occur, but since most mutations are harmful, a creature which had too many would not long survive. Atomicity here is the consequence of a stability of organization which itself is a prerequisite for the continued existence of creatures of that general kind.

In all these cases it is perhaps fair to see atomicities as arising where there are large amounts of energy available, gravitational in the case of the galaxies, kinetic in the case of turbulence, and chemical or electrochemical in the case of living matter. In such cases there seems to be a tendency to divide into units and this apparently makes for stability.

I ought perhaps to deal with one possible objection, that some of these atomicities may be due to the observer. We can only have a limited number of names, and we apply them somewhat arbitrarily to classes which may have no sharp edge. I think this may be true to a slight extent, but in the cases I have collected at least, and in many others, there is a real physical effect; that is, there are a great many individuals greatly alike in any particular quantity, and then a large gap before one comes to any more.

In a sense the subject that I am discussing is one of the oldest in philosophy, in that it is linked with the idea of universals, that is of names for groups of things, and of course the controversy between those who held that the groups had a real existence (the realists), and those who held they were only names (the nominalists), raged throughout the whole Middle Ages. I am in no sense a philosopher, and I dare not go further into this aspect of the subject. I do not think, though, that what I have presented to you can be explained as merely a matter of words. It seems to me that atomicity is as real and as prevalent in nature as it is in the modern factory, and for those who dislike what they refer to as "this machine-made age" it may be some consolation that it is, at least, foreshadowed by nature.

GEOPHYSICS.—*Radioactive pollution and civil defense.*[1] FRANÇOIS N. FRENKIEL, Applied Physics Laboratory, The Johns Hopkins University.

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The present development of nuclear sciences points to continuously increasing possibilities of the use of nuclear technology in the civilized world. This new source of power may serve to further advance our civilization or to destroy it. We often describe the possible damages of a nuclear war. We should also keep in mind the dangers of radioactive pollution whether produced by wartime or by peacetime applications of nuclear reactions. Radioactive pollution control measures will be less costly if planned while the development of nuclear power is still in its infancy. As to civil defense plans against nuclear warfare, their effectiveness should be measured not by the number of possible casualties but by the number of people who can be rescued. Since any such plan must be based on the understanding and active support of the population, it is urgent to correct the widespread impression that no effective civil defense plan can exist. Many of the studies and control measures referring to radioactive pollution are similar to those which can be used in conventional atmospheric pollution problems. This similarity is important when one wishes to evaluate the costs of effective methods of protection from dangers of atmospheric contamination. In urban planning, for instance, many of the measures suggested with the desire of reducing atmospheric pollution from combustion and other chemical reactions will also be applicable as civil defense measures. We will therefore refer in what follows not only to radioactive pollution but also to some problems of conventional air pollution.

As far as human protection from air contamination is concerned it is necessary to limit the contacts of the population with the pollutants and restrict the irradiation doses (*1*). The safe limits will be based on "allowable threshold concentrations" for acute short-time exposure effects and on "allowable long-exposure concentrations." Consideration should also be given to the possible dangers of polluting the world atmosphere to such a degree that there may be an appreciable effect on the climate or health of the population.

In fixing the allowable concentrations one must take into account the fact that too stringent limitations will impose great costs and operating difficulties on many indispensable or useful activities of the population. On the other hand, insufficient restrictions may result in harmful effects on the health of the population and damage to property. Therefore, the costs and operational difficulties of these limitations should be measured by their beneficial effects.

At least four general classes of methods to limit contacts between the contamination and the population can be considered:

(a) reducing the amount of atmospheric pollutants,
(b) moving the contaminating sources away from the population,
(c) moving the population away from the contaminating sources,
(d) isolating the population from contact with the contaminants.

In industrial and urban pollution we are mainly concerned with the first two classes, which consist of a control over the sources of pollution. In civil defense studies we are primarily concerned with the last two classes involving the destination of the pollutants and the population behavior in avoiding dangerous contacts with them. In all cases it will be important to evaluate the costs and effects of various methods of pollution control and of civil defense strategies.

To make such an evaluation one can use mathematical models of atmospheric pollution, which include in their description: the pollution sources, the nature of the pollutants, their emission conditions, the chemical reactions and other changes to

[1] This work was supported by the Bureau of Ordnance, Department of the Navy, under Contract NOrd 7386. The paper was presented at the Joint Meeting of the American Geophysical Union and the American Meteorological Society in Washington, D. C., May 4, 1956.

which they are subjected, the pertinent meteorological conditions, the topographical situation of the area, etc. Using appropriate equations one can then determine mean concentration patterns of the pollution as a function of the hour of the day. The relative contributions of each of several pollution sources to the contamination at each point of the area can then be evaluated, as well as the effects of changes in the operation of the pollution sources on the expected pollution patterns.

In the case of radioactive pollutants one will be interested not only in the concentrations of atmospheric pollutants but also in the solid and liquid pollutants which have accumulated on the ground. The radiological hazards will be due to the added effects of the pollutants which come into contact with the population and those which radiate from some distance whether they are in the air or on the ground. One must, of course, take into account the differences between the radioactive decay times of various contaminants when determining the pollution pattern.

As an example of the results which can be obtained with a mathematical model of atmospheric pollution, we have used Los Angeles County for which extensive data on the meteorological conditions and the distribution of pollution sources are available. A large part of the County is located in a basin bordered on two sides by a mountain chain. Temperature inversions frequently act as a relatively impermeable lid under which the pollutants accumulate. Los Angeles County is therefore a good proving ground for atmospheric pollution studies. The pollution sources include: industry, motor-car exhausts, oil and gas heating, and refuse incinerators. The pollutants emitted by those sources include nitrogen dioxide and hydrocarbons which produce ozone as a result of a photochemical reaction (*2*). We have described elsewhere (*3*) how such a mathematical model can be used to determine:

(a) temporary emergency measures to be taken when atmospheric pollution threatens to reach the allowable concentration levels,
(b) efficacity of various plans to reduce the pollution in an urban area,
(c) effects of a new pollution source on the mean concentration patterns,
(d) pollution patterns for a city after future expansions,
(e) efficacity of various solutions in urban planning on predicted pollution levels.

These results were based on average meteorological conditions corresponding to a selected month of the year, and their variations as a function of the hour of the day. On each day of the month the meteorological conditions depart from this average. This departure results in a deviation from the pollution patterns for a particular day, from the results obtained by this analysis. One can, of course, use as a basis for the analysis the meteorological conditions for each particular day and as a result determine much more correctly the concentration patterns. Since the use of mathematical models of atmospheric pollution requires extensive numerical computations, such an analysis will be practical only if high-speed computing techniques are used.

A method of civil defense against radioactive pollution involving the use of high-speed computors was suggested some years ago (*4*). Similar methods show promise of success in problems of peacetime air pollution of urban areas and can be used not only to analyze data on atmospheric pollution and urban planning but also on an operational basis in the control of atmospheric pollution.

In an area to be protected from pollutants we place a net of instruments measuring the directions and the magnitudes of the mean wind velocities, the character of the turbulence and other meteorological information such as, for instance, the characteristics of the temperature inversion. If the expected degree of contamination is determined before dangerous concentrations are reached, then the operational expenses of many methods of pollution abatement as well as the investment in special control equipment could be greatly reduced. Evacuation into the atmosphere is indeed one of the best and most economical methods of disposing of pollutants. If we are able to

determine the periods of time when such evacuation can be made without danger, then during those periods the use of the special equipment or special fuel will not be necessary. It is therefore important to determine the unfavorable conditions much more correctly than a human forecaster is able to do, since any action to reduce the emission of pollutants during the unfavorable time will be expensive. The meteorologist would alert the computing center whenever there seems to be a possibility of unfavorable meteorological conditions. The computing center would then take over the problem of continuously following the mean wind velocity pattern, the turbulence characteristics and the temperature inversion in the area. From these data the concentration of pollutants which may be reached over the area will be computed. At some chosen points of the area the concentration in contaminants will be measured and the results relayed to the computing center to improve the precision of the computation. The high-speed computation will determine what the expected concentration distributions will be if the operation of the sources of pollution continues without change. If, at any point in the protected area, the occurrence of a dangerous concentration is predicted, action would have to be taken to reduce the emission of pollutants. It will be possible to determine which individual sources contribute most to the dangerous concentrations, since the computation is done by adding the effects of the various sources. One will then find what the effects of shutting-down or reducing the production of pollutants at some of these individual sources will be on the predicted concentrations. As a result it may be sufficient to take such action at only some of the sources of pollution and limit the expense and inconvenience to a minimum.

The operational use of high-speed computing techniques is of particular interest in the protection from radioactive pollution. In this problem there is a difference between atmospheric pollution originating from a nuclear reactor, an experimental device exploding at a preassigned place and the burst of an enemy nuclear bomb. In the first two cases the location of the pollution sources and the general characteristics of pollutants are known. The problem is then somewhat similar to those considered in the study of conventional air pollution. In problems of civil defense the burst point of an enemy bomb is not well known in advance. An operational application of high-speed computing may therefore be of particular importance, since it makes possible rapid computations of several probable pollution patterns associated with various possible burst points. There is an essential difference between the most effective protection methods to be used after the explosion and those which should be used before the explosion.

After a nuclear explosion the dispersion of a nuclear cloud depends mainly on the meteorological conditions. If the information about the burst point, explosion characteristics and the nature of the radioactive pollutants is available to a computing center, then the probable pollution patterns can be predicted. Consideration may have to be given to evacuation versus use of shelters. The best protection methods may vary at each section of the area surrounding the burst point and may change at various times following the explosion. They will depend on the nature of the shelters and on the possible evacuation procedures and they will be influenced by the damage which the area has already suffered from blast and radiation effects. They will also depend on the indoctrination and susceptibility to panic of the population.

The problem of civil defense under threat of an immediate nuclear attack is quite different. Let us assume that enemy airplanes have been detected at some distance from, say, Washington, D. C. If the airplanes are detected several hours before they can reach Washington, then one cannot be certain that Washington is indeed the target and that the enemy is not planning to attack Baltimore, for instance. Even if the civil defense could suggest to the enemy where and how he should deliver his bomb, there is still a probability that he will not reach his target. Any civil defense measure must take into account the probability of having incorrect information about the enemy's target, the probability of an airplane being

destroyed by the military defense, the possibility that such a destruction will result in a nuclear explosion, etc. If for instance the population were evacuated, under the assumption that the enemy will attack Washington, and then Baltimore should become the target, the population may find itself moving into an area contaminated by radioactivity. An operational study would thus involve not only following the motion and the dispersion of nuclear clouds, but also the prediction of probable burst points using the information about the activity of the enemy and the possibility of his interception by military defense.

Peacetime preparation of civil defense plans should take into account this difference between the pre-explosion and the post-explosion cases when comparing evacuation versus shelter protection. These plans should evaluate how proper protection methods of both kinds will affect future civil defense operations during wartime and consider if and how these operations may have to be coordinated with military defense activities. One should also distinguish between the pre-explosion defense plans made when a threat of nuclear attack is imminent and dispersal plans for the population made well before a war starts.

Some of the advance civil defense plans may also have a beneficial effect on industrial pollution control. To make possible a rapid evacuation as well as speedy relief of a city after bombardment, improved highways and city roads may be necessary. Civil defense may also wish to consider the effectiveness of a proper subway system which could serve for both shelter and evacuation. Consideration must also be given to dispersal plans in urban building to reduce the probability of large scale destruction. Each of these solutions will reduce atmospheric pollution as well as simplify traffic. In urban planning it may therefore be desirable to keep in mind the necessities of civil defense together with those of urban traffic and atmospheric pollution abatement. Some city planning ideas may be considered too expensive as merely insurance against nuclear attack effects; they may, however, become quite acceptable if atmospheric pollution and traffic problems should also be taken into account.

Most civil defense considerations refer to simultaneous attacks of several, say, eighty cities. Since such an attack may indeed be possible the civil defense problems are national in scope and any plans for individual cities will have to be interrelated. One may safely claim that civil defense plans made for each single city, however good they may be individually, will not add to the best national plan for a simultaneous defense of eighty cities. Nor can such a general plan be dissected into the most effective plans for single city attacks.

One should be cautious to avoid the tendency to decide for the enemy what his future strategy will be. It may be important to assume several possible actions of the enemy and try to determine those which are most probable. Strategic defense plans should not be based on a single plan for each enemy action but involve several possible methods of defense. The selection of the most appropriate will have to be made at wartime and may be influenced by the overall interest of the country. There may be serious danger that the assumption of a particular enemy strategy and the preparation of a single defense plan will limit the military defense strategy or force it to ignore civil defense requirements and expectations. It is also possible that a single and rigid civil defense plan will limit dangerously the general policies of a nation.

An essential part of any civil defense system will be a complete communication system. No system will operate to its full capacity unless the information needed to make appropriate decisions can be rapidly collected, evaluated, and used and the necessary instructions forwarded to the population. Various methods of collecting data on the point of burst, the nature of the explosion, the motions of the nuclear cloud, the meteorological conditions, the damages, the traffic possibilities, etc., will be required. These methods may include the use of helicopters for direct observation and measurements of radioactivity levels. In some cases the best civil defense strategy may require an initial evacuation followed by

protection in shelters. In others it may appear desirable, but not always possible, to change the instructions to the population during the defensive operation according to sudden changes of the meteorological conditions.

If the operational use of high-speed computing techniques is to be applied, one must take the precaution of planning several interconnected computing centers, in order that the destruction of one or more of such centers not discontinue the civil defense operation. It would be incorrect to conclude that each large urban area should be provided with several computing centers. It may be possible to spread such centers over the whole country and plan proper communication facilities to make possible the use of any one of them to analyze the information from the attacked area. The use of these computing centers does not have to be limited to civil defense problems and could be extended to other purposes as well.

If there is no exaggeration in the publicly estimated numbers of casualties per nuclear bombardment, it should be expected that the number of those which could be rescued, with a properly used defense plan, is of a similarly large order of magnitude. An attack on numerous cities would then not only multiply the number of casualties but will also multiply the number of those which can be rescued. Let me repeat once more that as far as the protection of human lives is concerned, the importance of a civil defense plan should not be measured by the number of those which could be killed in a nuclear attack but by the number of those which can be saved.

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Whoever rejects faith in the reality of atoms and electrons, or the electromagnetic nature of light waves, or the identity of heat and motion, cannot be found guilty of a logical or empirical contradiction; but, he will find it difficult from his standpoint to advance physical knowledge.—PLANCK (1913).

MATHEMATICS.—*Generalization of a theorem of Konig.*[1] A. J. HOFFMAN, National Bureau of Standards.

(Received May 21, 1956)

Let R be a set with elements $p_1, \cdots, p_n$, $S = \{S_1, \cdots, S_m\}$ a family of subsets of R, and α a real number, $0 < \alpha < 1$. Denote the number of elements contained in a set T by $\overline{T}$, and the set of elements common to the sets T and U by $T \cap U$. In this note, we consider the question: does there exist a set $C \subseteq R$ such that

$$|\overline{C \cap S_i} - \alpha\bar{S}_i| < 1, \qquad i = 1, \cdots, m? \tag{1}$$

Note that if $\alpha\bar{S}_i$ is an integer, then (1) requires $\overline{C \cap S_i} = \alpha\bar{S}_i$. If $\alpha\bar{S}_i$ is not an integer, (1) requires that $\overline{C \cap S_i}$ be either of the two integers closest to $\alpha\bar{S}_i$. So our question concerns the existence of set C which has in common with each S_i a set of elements whose number is proportional to the number of elements in S_i, the proportionality factor being α.

Such a set C does not always exist; e.g., let $R = \{1, 2, 3\}$, $S_1 = \{1, 2\}$, $S_2 = \{2, 3\}$, $S_3 = \{3, 1\}$, $\alpha = \frac{1}{2}$. We prove below a simple sufficient condition for the existence of a solution of (1). As an application, we derive a well-known theorem of Konig [3]: Let R be a set with qk elements, and two families of subsets, $T = \{T_1, \cdots, T_q\}$ and $U = \{U_1, \cdots, U_q\}$. Assume further that $R = \boldsymbol{U}T_i = \boldsymbol{U}U_i$, $T_i \cap T_j = \phi$ (the empty set) if $i \neq j$, $U_i \cap U_j = \phi$ if $i \neq j$. (The foregoing conditions state that the family T is a "partition" of R, and so is the family U.) Finally, assume $\overline{T}_i = \overline{U}_i = k$, $i = 1, \cdots, q$. Then there exists a set $C \subseteq R$ such that $\bar{C} = q$, $\overline{C \cap T_i} = \overline{C \cap U_i} = 1$, $i = 1, \cdots q$. There are many proofs of Konig's theorem in the literature. A demonstration closely related to Konig's original proof, yet sharing the geometric spirit of the discussion offered below, may be easily deduced from the lemma contained in [2].

[1] This work was supported (in part) by the Office of Naval Research.

Our generalization of Konig's theorem requires consideration of the matrix A representing the incidence of elements of R with sets in S. Let $A = (a_{ij})$ be the incidence matrix defined

$$\begin{aligned} a_{ij} &= 1 \text{ if } p_j \in S_i \\ &= 0 \text{ if } p_j \notin S_i \end{aligned} \tag{2}$$

for $i = 1, \cdots, m$, $j = 1, \cdots, n$.

We also require the following definition: a (rectangular) matrix is said to have the *unimodular property* if every square submatrix has determinant 0, 1, or -1.

Theorem. If the matrix A has the unimodular property, then, for any α, $0 < \alpha < 1$, there exists a solution to (1).

Proof: For x a real number, let $[x]$ denote the greatest integer not exceeding x. Consider now the set of points satisfying the linear equation and inequalities

$$\sum_{j=1}^{n} a_{ij} y_j = \alpha\bar{S}_i, \tag{3}$$

for all $i = 1, \cdots, m$

such that $\alpha\bar{S}_i$ is an integer,

$$[\alpha\bar{S}_i] \leqq \sum_{j=1}^{n} a_{ij} y_j = 1 + [\alpha\bar{S}_i], \tag{4}$$

for all $i = 1, \cdots, m$

such that $\alpha\bar{S}_i$ is not an integer,

$$0 \leqq y_j \leqq 1, \qquad j = 1, \cdots, n. \tag{5}$$

This system is consistent, for the point $\bar{y} = (\alpha, \alpha, \cdots, \alpha)$ clearly satisfies (3), (4) and (5). Hence the set of solutions is a nonempty closed convex set K, which is, by (5), clearly bounded. Therefore, K admits vertices. Since A has the unimodular property, it follows [1] that every vertex has all of its coordinates integers. Let $\bar{y} = (\bar{y}_1, \cdots, \bar{y}_n)$ be any vertex. By (5), $\bar{y}_j = 0$ or 1. Let $C = \{p_j \mid \bar{y}_j = 1\}$. Then (3) and (4) imply (1).

A general theorem describing sufficient conditions for A to have the unimodular property is given in [1]. A special case worth mentioning occurs when the family S can be split into two subfamilies each of which has the property: if two subsets in the same family have a non-empty intersection, one is contained in the other. For example, a subfamily could be a partition of R. If each subfamily is a partition, if $\bar{S}_i = k$ $(i = 1, \cdots, m)$, and if we set $\alpha = 1/k$, then (1) becomes König's theorem.

Remark 1. The hypothesis that A have the unimodular property is not necesary for the existence of a solution to (1). Let $R = \{1, 2, 3, 4, 5, 6\}$, $S_1 = \{1, 2, 3\}$, $S_2 = \{3, 4, 5\}$, $S_3 = \{5, 6, 1\}$. Then the submatrix formed by the three rows of A and the first, third and fifth columns of A has determinant 2, so A does not have the unimodular property. On the other hand, for $0 < \alpha < \frac{2}{3}$, $C = \{2, 4, 6\}$ satisfied (1), and for $\frac{2}{3} \leqq \alpha < 1$, $C = \{1, 3, 5\}$ satisfies (1).

Remark 2. Since we know that any bounded r-dimensional closed convex set admits at least $r + 1$ vertices, we can estimate a lower bound for the number of solutions of (1). Since α is properly between 0 and 1, a point of any sufficiently small sphere containing $\tilde{y}$ satisfies (5). Clearly, such a point also satisfies (4). If (and only if) v is any vector orthogonal to all rows i of (3), then $\tilde{y} + ev$, for e sufficiently small in absolute value, will satisfy (3) as well as (4) and (5). This remark tells us that the dimension of K is $n - d$, where d is the dimension of the space spanned by all rows i such that $\alpha\bar{S}_i$ is an integer. Hence, the number of solutions of (1) is at least $n - d + 1$.

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However certain the facts of any science, however just the ideas derived from these facts, we can only communicate false or imperfect impressions to others, if we want words by which these may be properly expressed.—A. L. LAVOISIER.

ENTOMOLOGY.—*Type specimens of mosquitoes in the United States National Museum: II, The genus* Aedes (*Diptera, Culicidae*).

ALAN STONE, Entomology Research Branch, U. S. Department of Agriculture, and KENNETH L. KNIGHT, Bureau of Medicine and Surgery, U. S. Department of the Navy.[1]

(Received May 8, 1956)

The first part of this series dealing with the genera *Armigeres, Psorophora,* and *Haemagogus* appeared in this JOURNAL **45:** 282–289. 1955. The introductory remarks in that paper and especially those on early, possibly questionable, holotypes, apply equally well to this one. Following our treatment of nominal taxa requiring special attention we present a list of those in the collection based on unique specimens or for which holotypes were clearly designated.

We are particularly indebted to Dr. J. B. Schmitt and Dr. B. B. Pepper, of the Department of Entomology of Rutgers University, for giving to the U. S. National Museum most of the type material of mosquitoes from the New Jersey Agricultural Experiment Station, consisting of syntypes of five species described by Grossbeck and one species described by Coquillett.

Genus **Aedes** Meigen

Aedes aboriginis Dyar, Ins. Insc. Mens. **5:** 99. 1917.

A male, bearing the data, "Longmire Springs, Mt. Rainier National Park, Washington, 18. VI.17, H. G. Dyar," was selected as lectotype by Knight (1951, p. 96).

Culex aestivalis Dyar, Journ. New York Ent. Soc. **12:** 245. 1904.

This was based upon adult specimens referred to *Culex reptans* Meigen by Dyar (1904, p. 38) and a description of the larva. No type material was mentioned in either publication. The collection contains a male with terminalia mounted on a slide. The pinned specimen bears the labels: "2790 iss III.04 / H. G. Dyar Collector / See slide No. 22 / Aedes aestivalis Dyar ♂ type." The slide bears a red type label with no number and the labels: "22 C. repitans [sic] 279.0 Kaslo B.C. Dyar III.04 / Culex (Culicada) aestivalis Dyar Type ♂ genitalia, Dec. 14, 1904." We select this as lectotype of the species. There are many other specimens from Kaslo, British Columbia, but none of these is marked as type.

Aedes stimulans albertae Dyar, Ins. Insc. Mens. **8:** 115. 1920.

The three syntypes from Edmonton, Alberta, are in the collection, and we select as lectotype the male collected May 17, 1919, which bears Dyar's determination and type label. The terminalia of this specimen are mounted on slide no. 1226.

Gymnometopa albonotata Coquillett, Proc. Ent. Soc. Washington **7:** 183. 1906.

This was originally described from five male and three female syntypes collected by A. Busck in the San Francisco Mountains, Santo Domingo, West Indies, Type no. 8297, U. S. National Museum. We select as lectotype an undissected male bearing the labels: "141.3 / SFrncsco Mts. St. Domingo W.I. Sept. 05 / Aug. Busck Collector / Type No. 8297 USNM" and Coquillett's determination label. The associated pupal skin of this specimen is mounted on a slide.

Aedes aldrichi Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 57. 1908.

The type locality of this species is Market Lake, Idaho, according to the original description and the U.S.N.M. type catalogue, and the description was based upon six females. The collection contains two females from Market Lake and four from Lewiston, Idaho, and it is probable that these are the original six on which the description was based and that Dyar did not notice when writing the data that they were not all from Market Lake. Dyar labeled one of the Lewiston specimens with a type label, but we prefer to select as lectotype one of the two from the published type locality.

[1] Studies upon which this paper is based were conducted under an exchange of funds from the Office of Naval Research (Biological Science Division) to the Smithsonian Institution. The opinions or assertions contained here are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the Naval service at large.

Aedes alleni Turner, Ins. Insc. Mens. **12:** 84. 1924.

The two syntype males are in the collection, neither bearing any collection data, but each with an unnumbered red type label. One bears a number, 1885, which associates it with a terminalia slide labeled: "Aedes alleni Turner. Type. Mission, Tex. Jan. 30, 1924. 1885." We select this specimen as lectotype.

Aedes allotecnon Kumm, Komp, and Ruiz, Amer. Journ. Trop. Med. **20:** 417, 1940.

This name was originally proposed in a key to the adults of the *Aedes* of Costa Rica and is validated by the comparative characters given in the key. The formal description by Kumm and Komp (1941, p. 18) described the female as well as the larva and male but only three males with associated larval skins are designated as types. These syntypes are in the collection and we select as lectotype specimen no. 156.

Aedes altiusculus Dyar, Ins. Insc. Mens. **5:** 101. 1917.

This was described from an unstated number of specimens from "Indian Henry's," Mount Rainier National Park, Washington. The collection contains a female and a male each bearing the label "Type No. 21545 U.S.N.M." These are labeled Longmire Springs, Wash., June 24, 1917. Presumably they were collected as larvae on June 13 at "Indian Henry's" and they emerged June 24. We select the male as the lectotype. There are two other females, dated June 25, that are presumably of the original series.

Stegomyia amesii Ludlow, Journ. New York Ent. Soc. **11:** 139. 1903.

This species was described from Samar, Leyte, and Luzon in the Philippines. Only one of the original syntypes is in the collection, and this is the only one entered in the type catalogue. It is rather certain that the other syntypes are lost. This is a female bearing the type label and the label "Stegomyia amesii Ludl., Oras, Samar, P.I., June–Dec. Type C.S.L." Knight and Hull (1952, p. 158) call this a holotype, but since no holotype was mentioned originally we here designate it as lectotype.

Aedes angustivittatus Dyar and Knab, Journ. New York Ent. Soc. **15:** 9. 1907.

This was described from 25 specimens from three localities in Costa Rica and Bluefields, Nicaragua. There are 50 specimens in the collection bearing original data but only one, a female, bears the type label. Other labels on this specimen are: "Port Limon, C.R. / Fredk Knab Collector / Aedes angustivittatus Dyar and Knab Type." This we consider to be the holotype.

Culex annulifera Ludlow, Journ. New York Ent. Soc. **11:** 141. 1903.

The lectotype female selected by Knight and Hull (1951, p. 226) is in the collection.

Finlaya aranetana Banks, Philippine Journ. Sci. **1:** 1001. 1906.

The lectotype male selected by Knight and Marks (1952, p. 543) is in the collection.

Aedes argentescens Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 55. 1908.

This species was described from six syntypes from Córdoba and Almoloya, Mexico. A male and a female, both from Córdoba, bear Museum type labels. It is impossible to determine which four of the remaining specimens bearing original data were intended to be syntypes. The male also bears the label "Aedes argentescens Dyar and Knab Type" and the rearing number 441.4. This specimen we select as lectotype. Unfortunately, there were 18 specimens originally under number 441.4, not all in the collection now, and it is impossible to determine which larval and pupal skins belong to this specimen.

Aedes argyrothorax Bonne-Wepster and Bonne, Ins. Insc. Mens. **7:** 179. 1920.

It was the intention of the authors of this species to deposit the type specimen in the Colonial Institute, Amsterdam, Holland, and an additional specimen, called a cotype, was deposited in the U. S. National Museum. No holotype was designated, nor has a lectotype since been selected. Knight and Marks (1952, p. 546) stated that the single "cotype" male in the U. S. National Museum was the holotype, but this is not the case. Dr. Bonne-Wepster informs us that the original specimens of all the new species described in the paper in which *argyrothorax* was described are in Amsterdam.

Aedes atlanticus Dyar and Knab, Journ. New York Ent. Soc. **14:** 198. 1906.

This is based upon a figure of the larva in the original publication and upon descriptions by

Smith and by Felt of what they took to be *Culex serratus* Theobald from the Atlantic coast of the United States. While several of the specimens in the collection may have been before Dyar and Knab, Smith, or Felt when they described this species, there is no certainty of this, and so we do not feel justified in selecting a lectotype from these specimens.

Culex atropalpus Coquillett, Can. Ent. **34:** 292. 1902.

This was described from 37 female and 3 male syntypes from Virginia, Maryland, Pennsylvania, and New Hampshire. The males and 31 of the females are now in the collection, none of them marked as type. We select as lectotype a female bearing the labels "Plummer's I., Md. 16.7.02 / H. S. Barber Collector."

Howardina aureostriata Grabham, Can. Ent. **38:** 171. 1906.

The original description of this species does not state the number of specimens but does state that they were collected at Newcastle, Jamaica, and that some came from bromeliads. In the collection there are seven specimens, each bearing the label "M Grabham Collector." Three have penciled "aureostriata" labels, one is dated April 1906, and one is labeled "Mavis Bank, in bromelias." It is quite possible that some or all of these are syntypes, but it would be difficult to prove. They should be considered if a neotype were desirable, but since the name is a homonym there is little need for type designation.

Culex aurifer Coquillett, Can. Ent. **35:** 255. 1903.

The three original female syntypes are in the collection, each bearing the label "Type No. 12022 U.S.N.M." We select as lectotype one of the two collected June 25, bearing Coquillett's determination label.

Aedes balteatus Dyar and Knab, Journ. New York Ent. Soc. **15:** 9. 1907.

Of the six original females, five now stand in the collection and one of these bears a type label. This we consider to be the holotype. It bears the labels "St. Domingo W.I. Aug. / Aug. Busck Collector / Type No. 10142 U.S.N.M. / Culex balteatus Coq. [sic]." The number 10152 in the original publication is a misprint.

Aedes (*Ochlerotatus*) *bicristatus* Thurman and Winkler, Proc. Ent. Soc. Washington **52:** 239. 1950.

According to the original description, "Type specimens have been deposited in the U. S. National Museum. Paratypes have been deposited. . . ." There are two specimens in the collection bearing determination labels with a red penciled border. These are presumably the "types." Of these two, a male and a female, we select as lectotype the male bearing the label "Lakeport, Lake Co. 10 March 1950. reared 39.5 ♂ Eric C. Winkler." The pupal skin and terminalia of this specimen are on two slides.

Culex borealis Ludlow, Can. Ent. **43:** 178. 1911.

This was described from an unstated number of specimens collected in Alaska in June, July, and August. There are five females of the syntype series in the collection, apparently all collected at Fort Gibbon, Alaska, in July. Each bears the label "Type No. 27809 U.S.N.M.," and they appear to be conspecific. We select as lectotype one labeled in Ludlow's handwriting "Culex borealis Ludl. Fort Gibbon Alaska July, C.S.L. Types." This specimen appears to have been correctly determined as a synonym of *communis* De Geer.

Culex bracteatus Coquillett, Proc. Ent. Soc. Washington **7:** 184. 1906.

The four original females are in the collection, only one bearing a type label. This, which also bears Coquillett's determination label, we consider to be the holotype.

Stegomyia busckii Coquillett, Can. Ent. **38:** 60. 1906.

The syntypes, two males and one female, are in the collection, each labeled "Type No. 9139 U.S.N.M." We select as lectotype the undissected male bearing Coquillett's determination label of, "Gymnometopa busckii Coq." It was collected in a cocoa plantation on Dominica, July 28, 1905, by August Busck.

Aedes cacothius Dyar, Ins. Insc. Mens. **11:** 44. 1923.

The six female syntypes are in the collection, all bearing the identical data as published. We designate one of these as lectotype.

Aedes callithotrys Dyar, Ins. Insc. Mens. **8:** 16. 1920.

Of the 816 specimens determined by Dyar as this species, he selected and labeled a male and a female as types. We select as lectotype the male, bearing the labels "1159 / White Horse, Y.T. VII.17.1919 / H. G. Dyar / Type No. 22616 U.S.N.M. / Aedes callithotrys Dyar ♂ Type." The terminalia are on slide no. 1159.

Aedes campestris Dyar and Knab, Journ. New York Ent. Soc. **15:** 213. 1907.

This was described from a number of syntypes from various localities in Saskatchewan and Utah. Fourteen of these are in the collection, one male and one female having been labeled as type. We select as lectotype the female which is indicated as type and bears the labels "19.VI.07 / Oxbow, Sask. / Fredk Knab Collector."

Aedes (*Ochlerotatus*) *camposanus* Dyar, Ins. Insc. Mens. **6:** 128. 1918.

This species was described from a male and a female from Guayaquil, Ecuador, designated as types, and 52 other specimens also from Guayaquil. We select as lectotype the male of the two "types."

Aedes centrotus Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **4:** 747. 1917.

A female labeled "White River, Ont. 25.VI.07 / Fredk Knab Collector" was selected as lectotype by Knight (1951, p. 98).

Aedes (*Stegomyia*) *christianus* Dyar, Ins. Insc. Mens. **9:** 148. 1921.

The syntype series of this consisted of five males and three females in the U. S. National Museum and the private collections of C. W. Howard and C. S. Banks. The collection contains the two male and one female syntypes said to be deposited in the U. S. National Museum. We select as lectotype the male bearing the labels "Honam 3-4-20 / 1429 / Canton China / C. W. Howard / Type No. 24142 U.S.N.M. / Aedes christianus Dyar Type." The terminalia are on slide no. 1429.

Aedes stimulans classicus Dyar, Ins. Insc. Mens. **8:** 113. 1920.

The two male and one female syntypes are in the collection. Since this subspecies was based largely on characters of the male terminalia, we select as lectotype the whole male mounted on a slide.

Aedes condolescens Dyar and Knab, Journ. New York Ent. Soc. **15:** 11. 1907.

This was described from 24 specimens from five localities in the Bahamas. Nineteen of these are in the collection and one only bears a type label. This female is labeled "Nassau 6-24'03 Bahama Is. / T. H. Coffin Coll. #10 / Type No. 10248 U.S.N.M. / Aedes condolescens D & K. Type." We consider this to be the holotype.

Aedes cuneatus Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 54. 1908.

Two specimens of the original 35 are labeled with U.S.N.M. type labels, a female and a male. The female also bears the label "Aedes cuneatus D. & K. Type" and the rearing number 422.19. We select this specimen as lectotype. It was collected at Córdoba, Veracruz, Mexico, January 20, 1908, pupated January 28, and emerged January 31. There are two larval skins and a pupal skin associated with this type specimen. The other syntypes are not labeled as such and cannot be distinguished from similarly unlabeled syntypes of *Aedes argentescens* Dyar and Knab.

Culex curriei Coquillett, Can. Ent. **33:** 259. 1901.

This was described from five females from North Dakota, Colorado, Idaho, and California. Of these, only two from Boise, Idaho, have been found, one of them bearing the label "Type No. 5798 U.S.N.M." and Coquillett's determination label. This we consider to be the holotype since it is the only specimen bearing the type number, it bears Coquillett's determination label, and Boise is the only locality that Coquillett entered in the Museum type catalogue. We do not feel that Dyar and Knab (1906, p. 202) were justified in selecting a North Dakota specimen as lectotype or that this selection is acceptable.

Aedes cyclocerculus Dyar, Ins. Insc. Mens. **8:** 23. 1920.

The lectotype male selected by Knight (1951, p. 93) is in the collection.

Aedes cyprius Ludlow, Ins. Insc. Mens. **7:** 160. 1920.

This was described from 22 females collected in Siberia. There are 9 specimens bearing type

labels and 11 others that are probably of the original series. The locality of any one of the specimens labeled as type cannot be determined since only three of them bear any locality labels, and each one of these is marked both Selenga and Verkhne Udinsk with the dates July and August. We have selected one of the better specimens as the lectotype.

Grabhamia de Niedmannii Ludlow, Can. Ent. **36:** 234. 1904.

Although this was apparently described from several specimens, only one is in the collection. This bears a red type label (no number) and a label in Ludlow's handwriting reading "Grabhamia de niedemanni n. sp. Ludlow, Benicia Barracks, Cal. Type." We select this, a female, as lectotype. Four specimens in the British Museum sent to Theobald by Ludlow as this species are actually *Culiseta inornata* (Williston) rather than *Aedes squamiger* (Coquillett) of which *G. deniedmannii* is a synonym.

Aedes diantaeus Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **4:** 768. 1917.

This was described from two males collected in May and June at Dublin, N. H., by August Busck. The June specimen, with terminalia on slide no. 484, we here select as lectotype.

Culex dupreei Coquillett, Can. Ent. **36:** 10. 1904.

This was based on a specimen of each sex collected by J. W. Dupree at Baton Rouge, La. These are in the collection, each bearing the label "Type No. 7340 U.S.N.M." The female, which bears Coquillett's determination label, is lost except for the abdomen and one wing. We select as lectotype the male, which is in good condition, with its terminalia mounted on a slide.

Aedes epactius Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 53. 1908.

This was described from 10 syntypes in the collection from Mexico. One male and one female bear the red labels, "Type No. 11963 U.S.N.M." We select as lectotype the female, which also bears the labels "416.25 / Aedes epactius D. & K. Type." This was reared from a pupa collected at Córdoba, Veracruz, February 18, 1908, by Knab. The pupal skin of this specimen has not been found.

Aedes epinolus Dyar and Knab, Ins. Insc. Mens. **2:** 61. 1914.

This was described from 25 females from two localities in Peru. There are 24 of these in the collection, one labeled "type," the others "paratype." We select as lectotype the one labeled "type" from Ventanilla, Peru, February 4, 1914.

Aedes (Ochlerotatus) eucephalaeus Dyar, Ins. Insc. Mens. **6:** 127. 1918.

The original syntype series of this consisted of three males and two females collected by Bonne-Wepster in Paramaribo, Surinam, and labeled A, B, C. D, and L. These each bear the label "Type No. 21911 U.S.N.M." Adult A, larval and pupal skins B, and terminalia slide 971 from specimen D, are also labeled type by Dyar. We select as lectotype male specimen D with terminalia and associated larval and pupal skins on two slides.

Aedes euedes Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **4:** 714. 1917.

The syntypes of this are a male and female from Ottawa and a male and female from Trenton, Ontario, Canada. We select as lectotype the male from Trenton, May 24, 1900, with terminalia mounted on slide no. 446.

Aedes euplocamus Dyar and Knab, Journ. New York Ent. Soc. **14:** 199. 1906.

This was described from larvae collected at Zent, near Port Limón, Costa Rica. No topotypic material determined as this species has been found in the collection. While it might be possible to identify certain larval and pupal skins in the collection from the type locality as being the species described by Dyar and Knab, no reared adults have been found associated with these skins, and it would not be possible to be certain what specimens were originally studied. For this reason we feel it best to consider that no syntype material is available for lectotype designation.

Aedes fisheri Dyar, Ins. Insc. Mens. **5:** 19. 1917.

Five of the six original female syntypes from Lake Tahoe, Calif., June 20, 1920, are in the collection and we select as lectotype the one bearing Dyar's determination label.

Culex fletcheri Coquillett, Proc. U. S. Nat. Mus. **25:** 84. 1902.

The two syntype females are in the collection, and we have selected as lectotype the specimen bearing Coquillett's determination label.

Stegomyia gardnerii Ludlow, Can. Ent. **37:** 99. 1905.

The lectotype male selected by Knight and Hull (1952, p. 172) is in the collection.

Aedes gonimus Dyar and Knab, Ins. Insc. Mens. **5:** 165. 1918.

The four syntype females are in the collection all bearing type labels. We select as lectotype the one with Dyar's determination label.

Aedes grahami Ludlow, Ins. Insc. Mens. **7:** 154. 1920.

This was described from a male and a female from Siberia. We select as lectotype the male collected at Mostovoi in July.

Grabhamia grisea Ludlow, Can. Ent. **39:** 130. 1907.

It is not clear from the original description of this how many specimens were involved, but possibly there was only one. There is one female in the collection bearing an unnumbered U.S.N.M. type label and a label in Ludlow's handwriting as follows: "Grabhamia grisea n. sp. Ludlow type Boise Bks, Ida. July." We consider this to be the holotype.

Aedes grossbecki Dyar and Knab, Journ. New York Ent. Soc. **14:** 201. 1906.

This was described in a key to larvae from specimens determined by Coquillett as *Culex squamiger* Coquillett, and by reference to a description by Smith and Grossbeck (1905, p. 13) of *Culex squamiger*. There is apparently no type material of this species.

Aedes habanicus Dyar and Knab, Journ. New York Ent. Soc. **14:** 198. 1906.

This was described from larvae collected at Havana, Cuba, October 28, 1903, by John R. Taylor. The only material in the collection bearing these data is a slide with the fragments of a larval skin along with fragments of two larval skins of the genus *Psorophora*, one of which contains a *Culex* larval skin. We select as lectotype these *Aedes* fragments, consisting of a siphon, anal segment, and abdomen.

Aedes hemisurus Dyar and Knab, Journ. New York Ent. Soc. **14:** 190, 199. 1905.

The authors of this name called it a new species in the center heading and a new name at the end of the brief statement concerning it. There is no description except for the characters given in the key and reference to Grabham's figure (1905, p. 405) of the larva of *Culex confirmatus* from Jamaica. Although there are adults in the collection determined as *hemisurus* these are not associated with larval skins, and there are no larvae from Jamaica in the collection; and so it is probable that there are no specimens that can be said to be of the type series.

Aedes cinereus hemiteleus Dyar, Ins. Insc. Mens. **12:** 179. 1924.

The five syntypes were said to be all females, but one of them is a male. The specimen in best condition is a female from Lake Center Camp, Plumas County, Calif., the type locality, June 1, and we select this as the lectotype.

Aedes triseriatus var. *hendersoni* Cockerell, Journ. Econ. Ent. **11:** 199. 1918.

This was described from two females, one of which is in the collection and bears the labels "Box Elder Cr. Wyo. Aug. 25, '17. Schwabe and Henderson / Janthinosoma n. sp. / Psorophora hendersoni Ckll TYPE / Aedes triseriatus Say." The first three labels are in Cockerell's handwriting and the fourth was written by Dyar. This is the specimen which Knight and Marks (1952, p. 572) called a holotype. We here select it as lectotype.

Aedes (*Finlaya*) *heteropus* Dyar, Ins. Insc. Mens. **9:** 152. 1921.

The original 20 specimens, all labeled "Type No. 24865 U.S.N.M." are in the collection. We select as lectotype a male dated July 1, with terminalia on slide no. 1542.

Aedes hexodontus Dyar, Ins. Insc. Mens. **4:** 83. 1916.

The female lectotype from Fallen Leaf, Lake Tahoe, Calif., selected by Knight (1951, p. 93) is in the collection.

Aedes terrens homoeopus Dyar, Ins. Insc. Mens. **10:** 92. 1922.

This was described from three males from Costa Rica and Mexico, all of which bear type labels. We select as lectotype the specimen collected at Alajuela, Costa Rica, October 1921.

Aedes hortator Dyar and Knab, Journ. New York Ent. Soc. **15:** 12. 1907.

We consider as holotype of this species the female of the two original specimens bearing the type label.

Howardina inaequalis Grabham, Can. Ent. **39:** 25. 1907.

This was described from an unstated number of adult specimens, presumably of both sexes, and larvae. There are eight specimens in the collection labeled "Kingston, Jam. M. Grabham Collector." It is not certain that all these can be considered as syntypes of *inaequalis*, but it is quite probable that most of them are. There are two males labeled *inaequalis*, one of the labels being on the pinned specimen itself, the other on the slide of the terminalia. We select as lectotype the specimen with the determination label on the pin.

Culex inconspicuus Grossbeck, Ent. News **15:** 333. 1904.

This was described from three males and one female reared from larvae collected on Garret Mountains, Paterson, N. J. The collection contains all these, one of each sex being labeled as type and the second male as cotype. We select as lectotype the male type collected October 5, with the terminalia still on the specimen.

Aedes increpitus Dyar, Ins. Insc. Mens. **4:** 87. 1916.

This was described from an unstated number of specimens of a species that was very common in the Yosemite Valley. There are a great many specimens from the Yosemite Valley under this name in the collection, but only one specimen, a male, bears the type number. One female is also marked type but was not given a red type label. We select as lectotype the male, bearing the following labels: "FB25 / Fallen Leaf, Lake Tahoe, Cal. June 3, 1916 / Type No. 20350 U.S.N.M. / H. G. Dyar Coll. / Aedes increpitus Dyar Type ♂."

Aedes indolescens Dyar and Knab, Journ. New York Ent. Soc. **15:** 11. 1907.

This was described from 30 specimens from Cayamas and Havana, Cuba, and Santo Domingo, West Indies. One female bears the type label and this we consider the holotype. The other labels on this specimen are: "Cayamas, Cuba 8.5 / E. A. Schwartz collector / in woods / Aedes indolescens D. & K. Type."

Aedes infirmatus Dyar and Knab, Journ. New York Ent. Soc. **14:** 190, 197. 1906.

This was described in a larval key from specimens collected by Dupree at Baton Rouge, La. There are no reared adult specimens bearing original data and only three slides of larval skins of Dupree material. One slide contains two skins and is labeled as from New Orleans, one contains one larval skin with no locality label, and one from Baton Rouge contains two larval skins and fragments of pupal skins. This last slide was apparently prepared from alcoholic material subsequent to description of the species. These are topotypic and might be syntypic, but we prefer to select no lectotype from this poor and uncertain material.

Aedes innuitus Dyar and Knab, Ins. Insc. Mens. **5:** 166. 1918.

The two male and two female syntypes are in the collection, and we select as lectotype the male bearing Dyar's determination label, with the terminalia mounted on slide no. 708.

Aedes intrudens Dyar, Ins. Insc. Mens. **7:** 23. 1919.

Dyar stated that he selected as types specimens from Karner, N. Y., in the New York State Collection and specimens from Ontario and Alberta [U. S. National Museum]. We select as lectotype the specimens bearing the labels "White River, Ont. 25.VI.07 / Fredk Knab collector / See slide No. 467 / Type No. 21823 U.S.N.M." The terminalia are on slide no. 467.

Aedes ioliota Dyar and Knab, Ins. Insc. Mens. **1:** 77. 1913.

The four original females of this species, from Trinidad, West Indies (F. W. Urich collector), are in the collection, one labeled as type with a determination label, the other three labeled as

paratypes. The one labeled as type we consider to be the holotype.

Aedes (*Taeniorhynchus*) *jacobinae* Serafim and Davis, Ann. Ent. Soc. Amer. **26:** 14. 1933.

The original description of this species states that the male holotype and female allotype are to be deposited in the U. S. National Museum. The only specimens in the collection are a slide of the male terminalia bearing the labels "J. H. Sch. of Hyg. Protozoology Aedes jacobinae Davis Jacobina, Bahia, Brazil, Dec. 1931. J. Serafim / genitalia ♂ holotype," and a female, bearing the labels: "Jacobina, Bahia, Brazil Jan. 1932 / N. C. Davis Coll. / Slide *a* 29.III.49." This slide has not been found. The pin also holds the cleared female terminalia in glycerine. It is probable that only the terminalia of the holotype are in existence.

Culex knabi Coquillett, Proc. Ent. Soc. Washington **7:** 183. 1906.

This was described from seven syntype females. Six of these are in the collection but none bears a type label. We select as lectotype the specimen bearing the labels "No. 291*a* / See F. Knab's Entom. notes / Tehuantepec, Oax., Mex. / Culex knabi Coq." The pupal skin of this specimen is mounted on a slide.

Culex labeculosus Coquillett, Ent. News **16:** 116. 1905.

The eight syntypes are in the collection and we select as lectotype a male bearing the labels "Type No. 8314 U.S.N.M. / Slide 707 / Culex labeculosus Coq. / Ent. News xvi.116, 1905 6 ♀ 2 ♂ 8314." The terminalia are on slide no. 707.

Verrallina laternaria Coquillett, Proc. Ent. Soc. Washington **7:** 184. 1906.

Four of the five original males of this have been found. Only one of these bears a type label and this one, which is also labeled "Verrallina laternata" [sic], we consider to be the holotype.

Culex lativittatus Coquillett, Ent. News **17:** 109. 1906.

This was described from a large series of both sexes from Santa Clara and Alameda Counties, Calif. There are 37 specimens in the collection that are probably of the original series. No one of these bears a type label. We select as lectotype a female bearing the labels "Arden 19 July 03 / L. S. Jr. U. Lot 45 Sub. 1 / Ochlerotatus lativittatus Coq."

Aedes leuconotips Dyar, Ins. Insc. Mens. **8:** 24. 1920.

The male selected as lectotype by Knight (1951, p. 93) is in the collection.

Taeniorhynchus lineatopennis Ludlow, Can. Ent. **37:** 133. 1905.

Knight and Hull (1953, p. 468) selected as lectotype one of three females, each bearing the label "Type No. 27794 U.S.N.M." Only one of these specimens bears any other label, and this label reads "Taeniorhynchus lineatopennis Ludl. Camp Gregg, Angeles, Pampanga, P.I. Sept. Type C.S.L.," in Ludlow's handwriting. This is the specimen that was selected as lectotype. The label is obviously erroneous, since it was Camp Stotsenburg at Angeles. To accept this lectotype designation we must assume that Ludlow wrote the wrong locality for the camp rather than the wrong camp for the locality. There seems no way of proving that this specimen is not one of the two original syntypes so we feel that the lectotype designation can stand.

Aedes lithocoetor Dyar and Knab, Journ. New York Ent. Soc. **15:** 201. 1907.

The five syntypes of this species are in the collection, a male and a female being labeled as types. We select as lectotype the female, bearing the following labels "101.5 / Rio Chagres, Panama / Collected by August Busck / Type No. 10868 U.S.N.M. / Aedes lithocoetor D. & K. Type." No larval or pupal skin has been found for 101.5.

Aedes (*A.*) *margarsen* Dyar and Shannon, Ins. Insc. Mens. **13:** 80. 1925.

The male selected by Laffoon (1946, p. 237) as lectotype is in the collection.

Grabhamia mediolineata Ludlow, Can. Ent. **39:** 129. 1907.

This was apparently described from several female specimens. There are two in the collection that are apparently syntypes. One bears the labels "Type No. 10282 U.S.N.M. / mediolineata Ludlow." The second is labeled "Type No. —— U.S.N.M. / Grabhamia mediolineata n. sp.

Ludlow, Fort Lincoln, N. D." We select the second of these as lectotype since it has the locality label on it and it is somewhat the better specimen.

Stegomyia mediovittata Coquillett, Can. Ent. **38:** 60. 1906.

This was described from 34 specimens collected by August Busck in Santo Domingo, West Indies. The collection contains one male bearing the type label and many more than 33 specimens bearing original data. It is not possible to pick the original syntypes from these, but we accept the specimen marked as type as the holotype. This bears the labels "99.4 / St. Domingo W. I. Aug. / Aug. Busck Collector / Type No. 9138 U.S.N.M. / Gymnometopa mediovittata Coq." The larval and pupal skins are mounted on a slide.

Aedes melanimon Dyar, Ins. Insc. Mens. **12:** 126. 1924.

This was described from 15 females and 2 males, and all of them are in the collection. Five are labeled as types, including the 2 males, and the rest as paratypes. We select as lectotype one of the 2 males with terminalia mounted on slide no. 1955.

Aedes mercurator Dyar, Ins. Insc. Mens. **8:** 13. 1920.

This was described from 65 specimens collected at Dawson, Yukon Territory, July 1919. There are 84 specimens in the collection bearing the original data. One male and one female bear the type label and Dyar's determination label. We select as lectotype the male, with terminalia on slide no. 1165, collected July 15, 1919.

Aedes meridionalis Dyar and Knab, Journ. New York Ent. Soc. **14:** 195. 1906.

This was described in the larval stage from a specimen collected at Las Loras, near Puntarenas, Costa Rica, which had been determined by Coquillett as *Janthinosoma musica* Say. There are 22 topotypic adult specimens and several larval skins collected by Knab. One male bears the labels "No. 333*b* See F. Knab's Entom. notes / Las Loras nr. Puntarenas, C. R. / Aedes meridionalis D. & K. Type." Since the species was described from the larva, we select the larval skin associated with this adult as the lectotype. The pupal skin and the adult are part of the same individual, but left undescribed in the original publication. No specimen from the type locality bears any determination label by Coquillett.

Catatassomyia meronephada Dyar and Shannon, Ins. Insc. Mens. **13:** 71. 1925.

This was described from 16 females from Los Banos, Laguna, Luzón, Philippine Islands. Fifteen of these syntypes are in the collection and one in the British Museum. We select as lectotype a specimen collected May 12, 1921, bearing the additional label "Mt. Makiling 1500-2000 Ft."

Aedes metalepticus Dyar, Ins. Insc. Mens. **8:** 51. 1920.

There are seven specimens in the collection labeled "Type No. 22714, U.S.N.M." and apparently five specimens were returned to Italy. It is probable that Dyar intended the one male to be the type, although it is not clear from the original description. We select as lectotype this male, from Scais, July 19, 1901, bearing Dyar's label "Aedes metalepticus Dyar Type ♂," with the terminalia on slide no. 1236, also labeled "type."

Aedes metoecopus Dyar, Ins. Insc. Mens. **13:** 30. 1925.

The original description mentions no types, Dyar merely stating that both sexes were before him, and we know only that the specimens came from Ecuador. There are nine specimens from Ecuador in the collection, but only one of each sex bears a Museum type label (without number). We select as lectotype a male bearing the labels "2107 / 86 / Ecuador F. Campos R. / Aedes (Finlaya) metoecopus Dyar Type." The terminalia are on slide no. 2107.

Aedes (*Skusea*) *miachaetessa* Dyar and Shannon, Ins. Insc. Mens. **13:** 78. 1925.

The lectotype female selected by Knight and Hull (1953, p. 478) is in the collection.

Aedes stimulans mississippii Dyar, Ins. Insc. Mens. **8:** 113. 1920.

The two syntypes, male and female, are in the collection, and we select as lectotype the male, which bears Dyar's determination and type label in addition to the Museum type label. The terminalia are mounted on slide no. 1263.

Culex mitchellae Dyar, Journ. New York Ent. Soc. **13:** 74. 1905.

This was described from 61 specimens, one from Jacksonville, Fla., being selected as type [holotype]. Only one of the specimens bears the type label, and it also bears the labels " ♂7 & 8 / Miami, Fla. / H. G. Dyar Collector / Culex mitchellae Dyar Type 8402." The published type number is 8407, and the slide of larval and pupal skins bears the label "Culex mitchellae Dyar Type 8407 Culex sylvestris Theobald ♂7 & 8." The slide also contains a larval and pupal skin of *Aedes vexans* (Meigen). On going to the type catalogue we found that the number 8407 is assigned to *Mimagyrta pulchella* and that *Culex mitchellae* is listed under number 8402, with Jacksonville, Fla., as the locality. We conclude that 8402 is the correct type number, which was changed to 8407 in labeling the slide and in publication by error, and that the type locality is Jacksonville, since Miami is not even listed in the original publication as one of the localities for the species.

Aedes (*Heteronycha*) *muelleri* Dyar, Ins. Insc. Mens. **8:** 81. 1920.

The original description of this species states, "Types, No. 22826, U. S. Nat. Mus; male and female, Mexico City, Mexico (Juan Müller)." These two syntypes are in the collection with the male labeled as type, the female as paratype. We select as lectotype the male, with terminalia mounted on slide no. 1253.

Aedes mutatus Dyar, Ins. Insc. Mens. **7:** 24. 1919.

Dyar labeled one of the numerous males from Missoula as type and this we consider to be the holotype. It bears the labels "Missoula, Mont. July 6, 1917 / H. G. Dyar Coll. / Type No. 21918 U.S.N.M. / Slide 663 / Aedes mutatus Dyar Type." The slide is of the terminalia.

Stegomyia nigritia Ludlow, Can. Ent. **42:** 194. 1910.

This was described from two females collected at Cottabato, Mindanao, Philippine Islands, in December. There is a single female in the collection bearing the label "Stegomyia nigritia n. sp. Type P. I. Nov." Since no other specimen has been found that could be considered as the type, we select this specimen as lectotype in spite of the difference in date of collection.

Grabhamia nigromaculis Ludlow, George Washington Univ. Bull. **5** (4): 83. 1906.

This was described from an unstated number of specimens collected at Fort Keogh, Mont., and Fort Lincoln, N. D. The collection contains five syntypes labeled "Type No. 10147 U.S.N.M." Four were collected at Fort Keogh, September 1906, and the fifth at Fort Makenzie, Wyo., a place not mentioned in the original description. We select as lectotype the female from Fort Keogh bearing a determination label.

Aedes niphadopsis Dyar and Knab, Ins. Insc. Mens. **5:** 166. 1918.

The three syntype females are in the collection, and we select as lectotype the one bearing Dyar's determination label.

Aedes (*Finlaya*) *niveus nipponicus* LaCasse and Yamaguti, Mosquito Fauna of Japan and Korea, pt. **2:** 79. 1948.

The original description of this species designates no types but states that it was collected in a number of places on Kyushu and Honshu, Japan. A male and female in the collection are labeled as types, but since these were collected on August 29, 1949, more than a year after the species was published, they cannot be considered as types. The earliest adult labeled *nipponicus* was collected in May 1948, still too late for the March 1 publication. There is a single larval slide collected in September 1947, but it is not labeled *nipponicus* and may not have been seen by LaCasse or Yamaguti. It is probable that there is no true type material in existence.

Culex nivitarsis Coquillett, Proc. Ent. Soc. Washington **6:** 168. 1904.

This was said to have been described from a female and a male collected at Paterson, N. J., May 12, by J. B. Smith, and the specimens returned to the collector. The New Jersey collection contained these two specimens, each marked as type, but the female is dated May 17. Both were from Garret Mountain. These are now deposited in the U. S. National Museum collection, and we select the female as lectotype, since the male lacks the abdomen and all but one leg.

Aedes obturbator Dyar and Knab, Journ. New York Ent. Soc. **15:** 9. 1907.

This was described from 22 specimens from Tarpon Bay, Bahama Islands, only 12 of which

are now under the name in the collection. Only one of these bears a type label, and this female we consider to be the holotype.

Danielsia pagei Ludlow, Psyche **18:** 128. 1911.

The lectotype female selected by Knight and Hull (1953, p. 463) is in the collection.

Aedes pagetonotum Dyar and Knab, Smithsonian Misc. Coll. **52:** 253. 1909.

A note in the collection reads, "Note re Aedes pagetonotum D. & K. Jan 28, 1925. Located 8 types. The 2 gone may have been sent to Dr. Hewitt by me not then known to be types. H. G. Dyar." The eight types are in the collection, seven of them bearing type labels. We select as lectotype the first specimen listed in the description, a male bearing the labels "15.5.00 / Ottawa / Through J. Fletcher / See slide No. 343 / Type No. 12057 U.S.N.M." The male terminalia are on slide no. 343.

Culex pallidohirta Grossbeck, Can. Ent. **37:** 359. 1905.

There are two syntype females of this in the collection, one labeled as cotype that has been in the collection for a considerable time, the other labeled female type and recently presented to the collection by Rutgers University. We select as lectotype this latter specimen, bearing the label "Orange Mts., N. J. V. 26."

Aedes palustris Dyar, Ins. Insc. Mens. **4:** 89. 1916.

This was described from an unstated number of syntypes in the collection. Several bearing the original data have been found and one male and one female bear type labels. We have selected as lectotype the male, bearing the labels "FKπ / Fallen Leaf, Lake Tahoe, Cal. June 6, 1916 / Type No. 20351 U.S.N.M. / H. G. Dyar Coll / Aedes palustris Dyar Type ♂."

Aedes palustris var. *pricei* Dyar, Ins. Insc. Mens. **5:** 16, 1917.

The number of original specimens of this variety was not stated, but inasmuch as there is only one in the collection bearing the type label "Type No. 21043 U.S.N.M." we consider this as the holotype. It is a female, also bearing the labels "Fallen Leaf, Lake Tahoe, Cal. June 9, 1916 / H. G. Dyar Coll / Aedes palustris var pricei Dyar. Type."

Reedomyia pampangensis Ludlow, Can. Ent. **37:** 94. 1905.

This was described from three specimens taken in September at Angeles, Pampanga, Luzón, Philippine Islands. No specimen bearing these data has been found in the collection, but there is one female bearing the labels "Type No. 27795 U.S.N.M. / Reedomyia pampangensis Ludl. Camp Wm. McKinley, Rizal, P.I. Oct. 25, Nov. 3, 05 Type." The last label is in Ludlow's handwriting. Knight and Hull (1953, p. 454) have accepted this as the holotype, but since it was collected after the publication of the name it does not seem possible to consider this as of the type series, and it is probable that there are no syntypes in existence.

Aedes panayensis Ludlow, Psyche **21:** 159. 1914.

The male lectotype selected by Laffoon (1946, p. 242) is in the collection.

Aedes (*Culicelsa*) *perichares* Dyar, Ins. Insc. Mens. **9:** 36. 1921.

This was described from nine males and five females from Ciruelas, Costa Rica. These syntypes are all in the collection, each bearing the label "Type No. 23972 U.S.N.M." We have selected as lectotype a female bearing the label "Aedes perichares Dyar Type."

Aedes pertinax Grabham, Can. Ent. **38:** 316. 1906.

This was described from an unstated number of specimens from Jamaica. There are three males and two females in the collection bearing the labels "Rec'd from Dr. Grabham 10 July 1906 / Kingston, Jam. IV.10.06 temp. pools." It is quite certain that these are syntypes, and we select as lectotype a male bearing Dyar's label "pertinax" and with the terminalia mounted on slide no. 206.

Aedes pionips Dyar, Ins. Insc. Mens. **7:** 19. 1919.

Dyar labeled a male and a female as types of this species, selected from 152 specimens. We select as lectotype the male bearing the labels "994 / B9 / White River, Ont. June 19, 1918 / H. G. Dyar coll. / Type No. 21922 U.S.N.M. / Aedes pionips Dyar Type." The terminalia are on slide no. 994.

Aedes pix Martini, Mosquitoes of Mexico: 55. 1935.

Two females were sent to the British Museum in 1950, and these were marked as cotypes by Mattingly (1955, p. 29). One of these was sent to the U. S. National Museum and was labeled as lectotype by John Lane. Through the kind offices of Mr. Mattingly, Dr. Weyer permitted this specimen to be deposited in the U. S. National Museum. Lane and Cerqueira, in Lane (1953, p. 652), state that the lectotype is in the British Museum, apparently forgetting that it had been deposited in Washington. The second specimen was in very poor condition and is probably lost.

Aedes plutocraticus Dyar and Knab. Journ. New York Ent. Soc. **15:** 11. 1907.

Fifty-eight of the original 63 specimens of this species are in the collection and a female bears the type label. We consider this to be the holotype. Its data are: "Nassau, Bahamas 6-21-03 T. H. Coffin Coll. #10."

Aedes podographicus Dyar and Knab. Proc. Biol. Soc. Washington **19:** 165. 1906.

Two specimens in the collection, a male and a female, bear type labels. We select as lectotype the female, bearing the labels "No. 325j. See F. Knab's Entom. Notes / Sonsonate, Salv. / Type No. 10015 U.S.N.M. / Aedes podographicus D. and K. Type." Number 325j applies to several specimens, no larval skins of which were saved.

Culex portoricensis Ludlow, Can. Ent. **37:** 386. 1905.

Syntypes of this stand under two Museum catalogue numbers in the collection, 10007 and 27804, the specimens apparently having been received and entered at two different times. We have selected as lectotype a male bearing the original data and the type no. 10007.

Culex pretans Grossbeck, Ent. News **15:** 332. 1904.

This was described from 15 females collected in four localities in New Jersey. There are 11 of these specimens in the collection, one labeled type and the others labeled cotype. The one labeled type was collected at Great Piece Meadow, N. J., May 12, and we select this as lectotype.

Aedes prolixus Dyar, Ins. Insc. Mens. **10:** 2. 1922.

"The three syntype males of this are in the collection and we select as lectotype the one from Anchorage, Alaska, with terminalia mounted on slide no. 1579.

Culex pullatus Coquillett, Proc. Ent. Soc. Washington **6:** 168. 1904.

The one female and ten males reared from larvae are all labeled "Type No. 8030 U.S.N.M." The female bears Coquillett's determination label, but we select as lectotype a male with terminalia mounted on slide no. 21. It is from Kaslo, British Columbia, and emerged June 12.

Aedes punctodes Dyar, Ins. Insc. Mens. **10:** 1. 1922.

The male lectotype selected by Knight (1951, p. 97) is in the collection, with the terminalia mounted on slide no. 1582.

Culex quadrivittatus Coquillett, Can. Ent. **34:** 293. 1902.

Seven of the original eight females are in the collection, and one of these bearing the type label and Coquillett's determination label we consider to be the holotype.

Aedes quaylei Dyar and Knab, Journ. New York Ent. Soc. **14:** 191. 1906.

This name was proposed for the salt-marsh form of *Culex curriei* Coquillett from the Pacific coast as treated by Quayle (1906, p. 4), and the only characters given are to be found in the key to the larvae. No specimens are labeled as types in the collection, and most of the specimens that might have been those seen by Dyar and Knab when they described *quaylei* are probably also the syntypes of *Culex lativittatus*. We do not feel that any specimens in the collection can be certainly identified as syntypes of *quaylei*.

Aedes (*Ecculex*) *rhecter* Dyar, Ins. Insc. Mens. **9:** 51. 1921.

This was described from one male and five female syntypes from Lomagundi and Lorenzo Marquez, Portuguese East Africa. The male bears the labels "Howard Coll. / Lomagundi Nov. '09 / Slide 709 / Type No. 23928 U.S.N.M. / Aedes rhecter Dyar Type," and we designate this as the lectotype. The terminalia are mounted on slide no. 709.

Aedes riparius Dyar and Knab, Journ. New York Ent. Soc. **15:** 213. 1907.

Only two of the original 68 specimens, a male and a female, are labeled as types. We select as lectotype the female, in excellent condition, collected June 21, 1907.

Stegomyia scutellaris var. *samarensis* Ludlow, Journ. New York Ent. Soc. **11:** 138. 1903.

This was described with no statement as to the number of specimens, time of collection, or locality other than Samar. The collection contains four females and two males, each bearing the label "Type No. 27790, U.S.N.M.," and one of these bears the additional label "Stegomyia samarensis Ludlow, Catabig, Samar, P.I., Type C.S.L." This is a female in fairly good condition, and we here designate it as lectotype.

Aedes sansoni Dyar and Knab, Can. Ent. **41:** 102. 1909.

This was described from five syntypes collected at Banff, Alberta. Dyar (1917, p. 114) selected specimen no. 10 as the type [lectotype].

Aedes septemstriatus Dyar and Knab, Journ. New York Ent. Soc. **15:** 10. 1907.

Two of the original three specimens are in the collection, and we consider the holotype to be a female bearing the following labels: "8 / Bluefields Nicar. / W. F. Thornton Collector / Type No. 10144 U.S.N.M. / Haemagogus septemstriatus D. & K. Type."

Taeniorhynchus sierrensis Ludlow, Can. Ent. **37:** 231. 1905.

There are 12 syntypes of this species in the collection, and we have selected as lectotype a female bearing the determination label in Ludlow's handwriting.

Culex siphonalis Grossbeck, Can. Ent. **36:** 332. 1904.

This was described from two females and five males reared from larvae collected at Livingston Park, N. J. All these specimens are in the collection, labeled "N Brunswick" with dates of V.9, V.10, and V.11. One female and one male are labeled as types and the rest as cotypes. We select as lectotype the female "type" collected May 10.

Culex squamiger Coquillett, Proc. U. S. Nat. Mus. **25:** 85. 1902.

The four female syntypes are in the collection, and we select as lectotype the one from Palo Alto (labeled "Stan U Cal.") and bearing Coquillett's determination label.

Culex sylvicola Grossbeck, Can. Ent. **38:** 129. 1906.

The original series on which this name was based consisted of 21 males and 20 females in the New Jersey Agricultural Experiment Station collection. A male and one female, each labeled type, and 24 "cotypes" are still in existence, and all but 13 of the "cotypes" are in the U. S. National Museum collection. We select as lectotype the female "type" labeled "Livingston Park, N. J. V.6."

Aedes tahoensis Dyar, Ins. Insc. Mens. **4:** 82. 1916.

This was described from an unstated number of specimens reared at Fallen Leaf, Lake Tahoe, Calif., the latter part of May and first of June 1916. The collection contains one undissected male labeled "FE14 / Fallen Leaf, Lake Tahoe, Cal., June 5, 1916 / Type No. 20352 U.S.N.M. / H. G. Dyar Coll. / Aedes Tahoensis Dyar Type ♂." There are a great many other specimens of the type series, but we select as lectotype the male mentioned above.

Aedes thibaulti Dyar and Knab, Proc. Ent. Soc. Washington **11:** 174. 1910.

This was described from a pair from Scott, Ark., both bearing a type label. The male bears the determination label, and the terminalia are on slide no. 524. The female is lost from the point except for one femur. We select the male as lectotype.

Aedes thorntoni Dyar and Knab, Journ. New York Ent. Soc. **15:** 10. 1907.

The seven original specimens are in the collection, and the female bearing the type number and Dyar's determination and type label we consider to be the holotype.

Aedes tormentor Dyar and Knab, Journ. New York Ent. Soc. **14:** 191. 1906.

This species was described in a key to the larvae from specimens collected in Baton Rouge,

La., by Dupree. A female in the collection bears the labels "Baton Rouge, La. / J. H. Dupree #106 / Culex serratus Coq. / Aedes tormentor D. & K. "serratus" [Dyar's handwriting]. There are also the fragments of a larval skin on a slide, but the slide is not numbered and may not belong to this specimen. Since there is no determinable larval material from the original series, we feel that no lectotype can be selected.

Aedes traversus Dyar, Ins. Insc. Mens. **13:** 215. 1925.

The three original syntype females, all bearing identical original data, are in the collection. We have labeled the best of these as lectotype.

Culex trichurus Dyar, Journ. New York Ent. Soc. **12:** 170. 1904.

The original description of this is of the egg and four larval instars. A female collected in British Columbia flying over a pool containing larvae of this species produced eggs, which hibernated over winter and produced larvae the following spring. The only adult material was said to be the badly rubbed original female and a broken male reared in Massachusetts by Dimmock from a similar larva. Neither of these specimens has been found in the collection. There is one slide of fragments of three larval skins, two of them, at least, not last stage, that are probably of the original series, but these are so poor that there seems no point in selecting a lectotype from them.

Culex trivittatus Coquillett, Journ. New York Ent. Soc. **10:** 193. 1902.

This was described from two females collected at Chester, N. J. Only one of these appears to be in the collection, and this bears the type label and Coquillett's determination label. This we consider to be the holotype. There is one other specimen from Chester, but this has no type label and bears the label "Aldrich Collection," which throws some doubt on its being the other original specimen.

Aedes uncatus Grabham, Can. Ent. **39:** 25. 1907.

This was described from an unstated number of adults, presumably of both sexes, and larvae, from Jamaica. There are two females and five males in the collection labeled "Kingston Jam. / M. Grabham Collector." We select as lectotype a male which also bears the labels "See slide No. 210" and "uncatus," the latter in pencil, probably by Dyar. The terminalia are mounted on slide no. 210.

Aedes vinnipegensis Dyar, Ins. Insc. Mens. **7:** 34. 1919.

Thirty-six of the original 37 females are in the collection, but only one bears the type number. This, which we consider to be the holotype, bears the original data and Dyar's handwritten label "Aedes vinnipegensis Dyar Type."

Aedes whitmorei Dunn, Proc. Ent. Soc. Washington **20:** 128. 1918.

The 12 syntype females of this are in the collection, all in rather poor condition. We select as lectotype one bearing the label "Aedes whitmorei Dunn. Cotype."

The following taxa are in the collection based either on unique specimens or on clearly designated holotypes:

Aedes acrophilus Dyar, 1917
Aedes (*A.*) *adustus* Laffoon, 1946
Anisocheleomyia albitarsis Ludlow, 1905
Aedes aloponotum Dyar, 1917
Aedes (*Finlaya*) *ananae* Knight and Laffoon, 1946
Aedes (*Stegomyia*) *arboricolus* Knight and Rozeboom, 1946
Aedes (*Howardina*) *argyrites* Dyar and Nuñez Tovar, 1927
Aedes (*Geoskusea*) *baisasi* Knight and Hull, 1951
Aedes (*Stegomyia*) *bambusicolus* Knight and Rozeboom, 1946
Aedes (*A.*) *bifoliatus* King and Hoogstraal, 1947
Culex bimaculatus Coquillett, 1902
Aedes (*Stegomyia*) *boharti* Knight and Rozeboom, 1946
Aedes (*Christophersiomyia*) *brayi* Knight 1947
Aedes (*A.*) *campylostylus* Laffoon, 1946
Culex cantator Coquillett, 1903
Aedes cataphylla Dyar, 1916
Aedes (*Finlaya*) *leucocelaenus clarki* Galindo, Carpenter, and Trapido, 1953
Aedes colonarius Dyar, 1924
Aedes (*Finlaya*) *croceus* Knight and Laffoon, 1946
Aedes (*Geoskusea*) *daggyi* Stone and Bohart, 1944
Aedes (*Skusea*) *dasyorrhus* King and Hoogstraal, 1946
Aedes decticus Howard, Dyar, and Knab, 1917
Aedes (*Finlaya*) *dobodurus* King and Hoogstraal, 1946
Aedes (*Finlaya*) *dorseyi* Knight, 1946

Aedes (*Stegomyia*) *downsi* Bohart and Ingram, 1946
Aedes (*A.*) *dux* Dyar and Shannon, 1925
Aedes dysanor Dyar, 1921
Aedes (*Ochlerotatus*) *edgari* Stone and Rosen, 1952
Aedes (*Finlaya*) *eucleptes* Dyar, 1921
Aedes euochros Howard, Dyar, and Knab, 1917
Aedes (*Mucidus*) *ferinus* Knight, 1947
Aedes (*A.*) *foliformis* King and Hoogstraal, 1947
Aedes (*Stegomyia*) *guamensis* Farner and Bohart, 1944
Aedes (*Stegomyia*) *gurneyi* Stone and Bohart, 1944
Aedes (*Stegomyia*) *hakanssoni* Knight and Hurlbut, 1949
Aedes (*A.*) *hamistylus* Laffoon, 1946
Aedes (*Finlaya*) *harperi* Knight, 1948
Aedes (*Ochlerotatus*) *hastatus* Dyar, 1922
Aedes (*Stegomyia*) *hensilli* Farner, 1945
Aedes (*Finlaya*) *hollandius* King and Hoogstraal, 1946
Aedes (*Stegomyia*) *hoogstraali* Knight and Rozeboom, 1946
Verrallina insolita Coquillett, 1906
Aedes iridipennis Dyar, 1922
Aedes (*A.*) *johnsoni* Laffoon, 1946
Aedes (*Finlaya*) *keefei* King and Hoogstraal, 1946
Aedes klotsi Matheson, 1933
Aedes (*Finlaya*) *knighti* Stone and Bohart, 1944
Aedes labradorensis Dyar and Shannon, 1925
Aedes (*Finlaya*) *lacteus* Knight, 1946
Aedes (*Stegomyia*) *laffooni* Knight and Rozeboom, 1946
Aedes (*Skusea*) *lamelliferus* Bohart and Ingram, 1946
Aedes (*Finlaya*) *laoagensis* Knight, 1946
Aedes (*A.*) *leilae* King and Hoogstraal, 1947
Aedes (*Finlaya*) *lewelleni* Starkey and Webb, 1946
Aedes (*Finlaya*) *leucopleurus* Rozeboom, 1946
Aedes leucotaeniatus Komp, 1938
Aedes (*Pseudoskusea*) *lunulatus* King and Hoogstraal, 1946
Aedes (*Finlaya*) *luzonensis* Rozeboom, 1946
Aedes (*A.*) *macrodixoa* Dyar and Shannon, 1925
Aedes (*Stegomyia*) *marshallensis* Stone and Bohart, 1944
Aedes masamae Dyar, 1920
Aedes (*Ochlerotatus*) *mathesoni* Middlekauff, 1944
Aedes (*Finlaya*) *medleri* Knight and Laffoon, 1946
Aedes milleri Dyar, 1922
Aedes (*A.*) *milnensis* King and Hoogstraal, 1947
Aedes mimesis Dyar, 1917
Aedes (*A.*) *multifolium* King and Hoogstraal, 1947
Aedes (*A.*) *neomacrodixoa* King and Hoogstraal, 1947
Finlaya nigra Ludlow, 1905
Pseudoskusea nigrotarsis Ludlow, 1908
Aedes (*Aedimorphus*) *oakleyi* Stone, 1939
Aedes (*Finlaya*) *okinawanus* Bohart, 1946
Aedes oligopistus Dyar, 1918
Popea palawanensis Ludlow, 1914
Aedes (*Ochlerotatus*) *fulvus pallens* Ross, 1943
Taeniorhynchus palliatus Coquillett, 1906
Aedes (*Stegomyia*) *pandani* Stone, 1939
Aedes (*Finlaya*) *paradissimilis* Rozeboom, 1946
Aedes (*A.*) *parasimilis* King and Hoogstraal, 1947
Aedes (*Stegomyia*) *paullusi* Stone and Farner, 1947
Aedes pearyi Dyar and Shannon, 1925
Aedes (*Stegomyia*) *pernotatus* Farner and Bohart, 1944
Aedes platylepidus Knight and Hull, 1951
Aedes (*Finlaya*) *plumiferus* King and Hoogstraal, 1946
Aedes poliochros Dyar, 1919
Aedes polyagrus Dyar, 1918
Aedes prodotes Dyar, 1917
Aedes (*Ochlerotatus*) *pseudodiantaeus* Smith, 1952
Stegomyia punctifemore Ludlow, 1921
Aedes (*A.*) *quadrispinatus* King and Hoogstraal, 1947
Stegomyia quasinigritia Ludlow, 1911
Aedes (*Stegomyia*) *quasiscutellaris* Farner and Bohart, 1944
Aedes (*A.*) *reesi* King and Hoogstraal, 1947
Aedes (*Stegomyia*) *riversi* Bohart and Ingram, 1946
Aedes (*Stegomyia*) *rotanus* Bohart and Ingram, 1946
Aedes (*Stegomyia*) *saipanensis* Stone, 1945
Aedes (*Finlaya*) *saperoi* Knight, 1946
Aedes schizopinax Dyar, 1929
Aedes (*Finlaya*) *scutellalbum* Boshell-Manrique, 1939
Aedes (*Stegomyia*) *scutoscriptus* Bohart and Ingram, 1946
Aedes (*A.*) *sentanius* King and Hoogstraal, 1947
Aedes (*Aedimorphus*) *senyavinensis* Knight and Hurlbut, 1949
Aedes (*Finlaya*) *sherki* Knight, 1948
Aedes (*A.*) *simplus* King and Hoogstraal, 1947
Aedes (*Finlaya*) *solomonis* Stone and Bohart, 1944
Aedes (*Finlaya*) *stonei* Knight and Laffoon, 1946
Aedes (*Finlaya*) *subalbitarsis* King and Hoogstraal, 1946
Aedes (*Levua*) *suvae* Stone and Bohart, 1944
Aedes thaxteri Dyar and Knab, 1919
Aedes (*Taeniorhynchus ?*) *thelcter* Dyar, 1918
Aedes (*A.*) *trispinatus* King and Hoogstraal, 1947
Aedes (*Finlaya*) *tsiliensis* King and Hoogstraal, 1946
Aedes (*Leptosomatomyia*) *variepictus* King and Hoogstraal, 1946
Culex varipalpus Coquillett, 1902
Aedes ventrovittis Dyar, 1916
Aedes tortilis virginensis Dyar, 1922
Aedes zoösophus Dyar and Knab, 1918

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

1409TH MEETING, APRIL 8, 1955

J. R. HELLER, of the National Institutes of Health, addressed the Society on *Some observations on cancer research and control*. Cancer control, from the standpoint of the Public Health Service is an entity that is susceptible to the same type of attack that has proved so successful in many other chronic diseases. The factors useful in this control may be summarized as follows:

1. Education, for both lay and professional people through all media.

2. Diagnosis, through the skillful application of all known methods.

3. Epidemiology: i.e., the study of its incidence, which shows very curious variation. For example, breast cancer is very low in Japanese women, stomach cancer very high in Japanese men, cervical cancer very low in Jewish women and two times higher in Negroes than in whites. Lung cancer six times higher in men than women, and particularly high in Austria, Scandinavia, and England.

4. Prevention, particularly through the removal of known carcinogens from the environment; e.g., beryllium, tar, sunlight.

5. Treatment: Surgery, radiation, and we hope ultimately chemical agents. (No one has been cured chemically yet, though some cancers respond favorably.)

6. Research in causes of cancers; and note the plural (there are probably as many kinds of cancer as there are other diseases, so we will have *cures*). Specific areas for research are: into carcinogenesis, into the nature and metabolism of cancers themselves, and into the "Host-parasite relationship." Illustrative of the latter is the fact that "an irascible old curmugeon hangs on a long time, while the gentle sweet person goes fast."

A series of colorful slides showing the changing and increasingly important cancer problem in the last forty years was shown. Cancer now ranks second in causes of death, and certain types, such as lung cancer, have shown phenomenal increases. This type has doubled in the past ten years and is 26 fold up over 40 years ago.

Dr. Heller also described in details the project in Shelby County, Tenn., where an attempt is

being made to examine all women 20 years of age and older by a technique that is equivalent to a biopsy of the cervix. In the past two years,165,000 —about 85 percent of the population—have been done, a thousand were found to be suspicious, and half of these to have an unsuspected malignancy. The distribution of types of cancer with age showed that the intra-epithelial type in the 20-year-olds could be expected to change to the invasive type after an average time of 19 years. There seems therefore to be a type of cervical cancer that can stay safe for long enough for the woman to bear children. The method gives promise of completely eliminating cervical cancer as a cause of death, though it requires continual screening and control.

A short description of the facilities of the National Institutes of Health and their operation was given.

A discussion by McNish, Potter, Tuckerman, Henderson, and others followed. The problem of how to deal with cancer quackery produced the greatest interest. (*Secretary's abstract.*)

1410TH MEETING, APRIL 22, 1955

GEORG WEINBLUM, of The Institut für Schiffbau, Hamburg, spoke on *Problems in ship theory*. The art of the shipbuilder is a very old one, but is nevertheless replete with unsolved problems in nearly every phase, because not only are the conditions which a ship has to meet immensely variable, but also because the construction, the materials, and the methods of propulsion have all changed enormously in relatively recent times.

The discussion was deliberately simplified by considering a ship to be a rigid body; thus avoiding all problems of strength and elasticity. The properties that define a ship are:

1. Buoyancy—i.e. water support—three types may be noted:
   (a) archimedean or displacement
   (b) hydroplane using hydrodynamic forces
   (c) hydrofoil
2. Stability
3. Powering
   (a) Resistance
   (b) Propulsion
4. Seaworthiness:
   (a) Safety and seakindliness
5. Maneuverability
6. Freedom from vibration
7. We omit strength—a study in itself

Of these properties only powering was treated in detail. Powering, the relation between resistance and propulsion, is most complex. A slide (originally due to von Karman) plotting speed attained against specific power—that is horse power per ton of the vehicle in question—was presented showing practically all of man's vehicles: the pedestrian, the horse, submarine, ship, airplane, tank, truck, auto, hydroplane and hydroglider. The power required seems to go up never less fast than the cube of the speed, but may in some cases be much worse, and all vehicles tend to lie in a band of slope 3.

A series of technical slides showing the variations in "wave resistance" with hull form was shown: Wave resistance per ton of displacement plotted against Froude number (v^2/lg). It was pointed out that esthetics are a delusive guide: an "ugly" form sometimes proving to have a remarkably low wave resistance.

The frictional resistance problem has not been seriously attacked as yet. Desperate measures suggested are: Removing the boundary layer, or substituting air for it. Success would save two thirds of the power. River craft of small burden have in fact been constructed to float on air bubbles.

The only worth-while improvement in propulsion since the invention of the screw propeller has been the addition of the nozzle. Cavitation still sets limits to any propeller's effectiveness.

Maneuverability and seaworthiness are also complex problems. The latter may be divided into "safety" and "seakindliness," but a quantitative theoretical approach is all but impossible. (*Secretary's abstract.*)

1411TH MEETING, MAY 6, 1955

CONYERS HERRING, of the Bell Telephone Laboratories, spoke *On the surface energy of crystals and its relation to sintering*. Sintering is the process by which small particles of metal, or other substance, can be forced, at relatively modest pressures and at temperatures below the melting point, to coalesce into a mass indistinguishable from the bulk material. This process lowers the free energy by decreasing the total surface area. Quantitatively, the free energy, "gamma," of Ni, Cu, etc., is about 1,000 ergs per cm^2, and complete sintering of 10 micron particles reduces gamma by about 1 calorie per mol: quite a small amount as reaction energies go, but sufficient.

The processes by which the material moves in sintering are:

(1) Plastic flow, which is the principal process with glassy materials, and is motivated by surface tension.

(2) Evaporation and condensation, motivated by the difference in surface tensions of convex and concave surfaces, leading through the Gibbs-Thomson relation to a difference in vapor pressures. Smaller particles—more convex surfaces—evaporate faster, while atoms condense more easily on concave surfaces.

(3) Volume diffusion, the migration of atoms or interstitial vacancies, motivated as before by the curvature and pressure.

(4) Surface diffusion, migration in the surface itself.

A plane surface of maximum density of atoms is a surface of minimum gamma. If now we cut a new plane not quite parallel to this plane we will increase gamma by an amount which is proportional to the angle at which we cut. A polar plot of gamma against angle—the "gamma plot"—shows a cusp at zero angle, if the absolute temperature is zero degrees. As the temperature rises this cusp rounds off and becomes first merely a minimum and then washes out altogether. In principle there should be a cusp, at zero degrees absolute, for all rational Miller indices, not merely for small ones but the high numbered cusps wash out very soon, as the temperature rises. (Mathematically we have here an infinitely dense set of points, with an infinite number of discontinuities in slope!) A polar plot of these cusps leads to the question "What shape gives minimum gamma?" Planes drawn perpendicular to the radius vectors in the polar gamma plot define a solid which will have the shape required. The shapes that result are spherical for liquids; ellipsoidal or lenticular for liquid crystals, or tactoids; solids with cusps at all rational orientations for crystals at zero; a finite number of cusps at other temperatures for crystals; and combinations of smooth surfaces, curves, or angles for other substances. All these should be found in nature, and existence depends upon the number and location of the cusps in the gamma plot.

This is true, of course, only for really small crystals. Large crystals are too easily perturbed.

The same considerations also hold for small empty spaces in sintered crystals. The spaces (like particles) assume shapes determined by the gamma plot.

Turning to the kinetics of crystal growth and of thermal etching, the results can be predicted if we know the equilibrium shape. Any smooth boundary plane will have a lower free energy than a bumpy one, but any tangent plane that is not a minimum gamma surface will etch and become bumpy. Very slight differences in free energy are very important.

Experiments to measure the surface tension of multi-crystalline solids were described. On certain assumptions the rate of creep can be calculated from the self-diffusion constants and agreement is excellent. A striking result is that a single crystal wire showed enormously increased resistance to stretching, as compared to a polycrystalline one. (*Secretary's abstract.*)

1412TH MEETING, MAY 20, 1955

IMMANUEL ESTERMANN, of the Office of Naval Research, spoke on the *Interaction of molecular beams with surfaces.* 1956 will be the centenary of the kinetic theory of gases, first proposed by Clausius and others in 1856. It is a curious fact that the basic assumptions underlying it—elastic spheres, random motion, velocity in hundreds of meters per sec, etc.—were not given experimental proof for a most unusually long time. They were taken on faith for nearly fifty years. Dunoyer's invention of the molecular beam method was recognized by Stern as at last providing a tool to measure the individual velocity, mass, and elasticity separately and directly as well as the number of molecules.

The answer to the question "Does molecular reflection behave specularly, or does it obey the cosine law?" seems to be "Neither." For He atoms impinging on LiF at low angles of incidence, specular reflection is only 25 per cent, or less. The remainder is partly diffracted, and partly reflected according to the cosine law. The DeBroglie theory provided a new approach according to which the anomalous reflections of atoms and molecules might be understood, in terms of space lattices of atoms in the reflecting surfaces. Even a crystal surface is "partially rough" to an atomic beam. The molecular beam method went beyond Davisson and Germer's work and showed that *all* particles, not merely elementary ones, are characterized by a De Broglie wave length. Thus the interaction between surfaces and gases is not describable in

general in terms of billiard balls, but in terms of waves and surface periodicities.

What happens to the velocity of the particle on reflection? Under the kinetic theory, it should be unchanged. Actually, the accommodation coefficient may vary all the way from zero to 1: (H on polished Pt: 0.3; CO_2 on Pt Black 0.98); in the latter case the particle takes up the temperature of the surface, in the former it remains unchanged.

We need to decide between two alternatives here: either all the particles are reflected with (say) a 75 percent accommodation coefficient, or some have unity and some zero in the proportion needed to give 75 percent. Helium on LiF turns out to have zero! Estermann and Bennett's work on K atoms at 305°, and on copper at 209°, 343°, and 401°C seems to show a coefficient of unity, and Maxwellian distribution after reflection. Future work on surfaces having intermediate values was promised. (*Secretary's abstract.*)

1413TH MEETING, JUNE 3, 1955

WILLIAM SHOCKLEY, of the Bell Telephone Laboratories and the WSEG, spoke on *The statistics of individual variation in productivity in research laboratories*. The talk reported the results of an Operations Research study of the productivity of scientists and its correlation with salary in various institutions. As criterion of productivity, the number of times a man's name appeared in Science Abstracts A over the past five years was taken. Nobel Prize winners, National Academy of Science members, and typical faculty members were compared. The Nobel winners published twice as much, and there is a strong correlation between quantity and quality.

By plotting the logarithm of the numbers of papers against the number of men who publish this number or less, the curve obtained is essentially a "normal" one, i.e., linear, except for the one or two very top men who are very productive. This plot is true for the NBS, Brookhaven, the Bell Laboratories (on the basis of patents taken out) and seems to be a general phenomenon.

A proposed law for productivity of the form $P_i = P_s \exp(-U_s\beta)$ would lead to such a plot. In this formula P_i is the individual productivity, P_s is the "situation" productivity, U_s the "mental barrier" to publication, and β is proportional to the reciprocal of the "mental temperature" of the individual, i.e. $1/kT_m$.

Why should the variation in rate be so large, when all are trained more or less alike? Rashevsky's idea was discussed: several ideas must inter-relate in the mind to produce an invention. The number of ideas the mind can hold at one time, therefore, is a very important parameter. "The seventh idea adds seven times the area."

Output versus actual pay was plotted for the NBS data. (Cautions to be observed are: References to faulty work, or to a compilation, are sometimes more frequent than to good ones; high pay people gravitate to administration with increasing age.) The cumulative publication figures for the four salary quartiles, plotted against age show the same linear plot, with an upturned tip. The first, highest, quartile publishes much more than the fourth, though some individuals in the fourth publish much more than some in the first. Many other criteria, of course, enter into the estimate of the value of a man to his organization.

It is of interest that the slope of the salary curve is only one fifth that of the productivity curve; that is 10 percent increase in salary is earned by 50 per cent increase in papers published.

In summary: the moral of the study is that one should always get a few men of high productivity, no matter what may be the cost. (*Secretary's abstract.*)

NOTES AND NEWS

PLASTIC SPRINGS

A practical procedure for mass-producing plastic springs has been developed by the National Bureau of Standards in work sponsored by the Army Ordnance Corps. Springs formed in this way[1] from glass fiber-reinforced resin have desirable mechanical properties for a wide range of applications. Until now plastic springs have been little used because suitable techniques for making springs of the types needed have been lacking.

Polymeric materials, such as plastics and rubbers, have a number of inherent advantages for use in springs for special purposes. For example, they are nonmagnetic and have low electrical and thermal conductivity. They can be molded directly to dimensions without the development of any considerable internal stress. Their high corrosion resistance should make them of value for applications in chemical plants and installations subject to acid fumes or to salt air. Other applications may benefit from the strength-to-weight ratios of plastics, which are often higher than those obtained with spring making metals. Also, the broad range of transparent and colored materials that can be used makes striking decorative effects possible.

The plastic springs are molded by drawing resin-soaked glass fibers through vinyl copolymer tubing and wrapping the loaded tubing in a helix around a mandrel. After curing in an air-circulating oven, the tubing is removed, leaving a solid plastic spring reinforced with glass fibers.

The most successful procedure uses vinyl chloride-vinyl acetate copolymer tubing having a ¼- or 5/16-inch inside diameter and a ⅛-inch wall thickness. Lengths of glass rovings are formed into a loose yarn, without twist, which is then doubled back to make a U-shaped bundle. This bundle is placed in a trough partly filled with liquid resin and is immersed until thoroughly soaked. A steel wire is threaded through the tubing, attached to the bend in the U-shaped bundle, and used to pull the bundle through the tubing. Considerable force is applied to the wire by means of a small windlass.

When the tubing is completely filled, the wire is disconnected and the ends of the tubing sealed with hose clamps. The tubing is wound on a mandrel, and the entire assembly is placed in an oven for curing under the conditions specified by the resin manufacturer. After removal of the tubing, postcuring is performed as required, and the springs are cut and ground to the finished length.

Of the resins studied, the most promising were epoxides and polyesters. These resins are better suited for spring applications on the basis of torsional moduli, temperature sensitivity, and ease of handling. In general, the polyesters are more sensitive to elevated temperatures than the epoxy resins, but the epoxy materials vary widely in this respect.

Springs made from polyester resins with glass fiber reinforcement showed good energy recovery properties after short periods of storage at −40°F., but these properties were adversely affected by 13 days' exposure to 135°F. while under stress. The best results were obtained with an epoxy resin cured with m-phenylenediamine. Springs made of this material had torsional moduli of rigidity of the order of 1.0×10^6 lb/in^2. In 2-inch lengths they deflected ½ inch under a static load of 25 lb. Three-inch springs of this type retained 40 per cent of their original energy when compressed to their solid length and stored at 135°F. for 13 days.

When the glass-epoxy springs were tested for recoverable energy a second time, higher values were invariably obtained. This characteristic "work tempering" of the epoxide resins was also demonstrated in torsion tests on nonreinforced plastic rods. An improvement of as much as 120 percent over the original available energy was indicated. Preloading the epoxide spring during storage or within 30 days before use would make it possible to utilize this property of the material.

The mechanical and thermal properties of the plastic springs can be varied widely by proper choice of materials and dimensions. For example, stiffer and probably more brittle springs result when the glass content is increased. At the same time a high degree of homogeneity in static properties can be achieved. Under a load of 25 pounds, 100 of the epoxy-resin springs had an average deflection of 0.53 inch with a standard deviation of 0.05 inch.

[1] For further details, see *Reinforced plastic springs*, by Frank W. Reinhart and Sanford B. Newman, Product Engineering (in press).

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